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No. 70

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APPLIED SCIENCES

GEOTHERMAL FIELD STRATIGRAPHIC PRESSURE GRADIENTS ANALYZED

Beijing TANKUANG GONGCHENG [PROSPECTING ENGINEERING] in Chinese No 2, 22 Apr 80 pp 1-8

[Article by Wang Zhongying [3076 0112 5391], Zhou Shaoguang [0719 7300 0342] and Tang Songran [3282 2646 3544]: "Categorization of Stratigraphic Pressure Gradients in Geothermal Fields and the Laws of the Stratigraphic Gradient in the Yangbajing Geothermal Field"]

[Text] Abstract: Geothermal reservoirs, whose hot fluid can be continuously replenished, are open-type structures, in contrast to oil and natural gas reservoirs which are basically of the closed type. Accordingly, the stratigraphic pressure classification methods used in drilling oil and gas wells are basically not applicable to geothermal boreholes. This article attempts to classify stratigraphic pressures in geothermal wells and studies the geothermal gradient laws of the Yangbajing Geothermal Field. The equations presented have been tested in 3 years' drilling experience at the Yangbajing field against the actual data from more than 10 wells.

1. Statement of the Problem

The Yangbajing Geothermal Field, Tibet, is our country's first high-temperature moist steam geothermal field. Because the reservoir is shallowly buried (already encountered at 20-30 meters) and is in a thick stratum (several hundred to more than 1,000 meters), while the cover layer is thin and brittle, it is very difficult to control the pressure within the well. If the specific gravity of the mud is too low, it may result in gushing, while if it is too high it may result in infiltration followed by gushing. An even more difficult problem is that if the uncased bottom section of the well is a bit too long, it may result in gushing in the upper section and infiltration below. In the first 2 years of prospecting, serious gushing caused stratigraphic subsidence, well-head explosions or surface cracking, resulting in the abandonment of 4 wells during the drilling process, drilling work was unable to continue, since there was a grave threat to construction safety.

The experience of well drilling at the Yangbajing Geothermal Field has posed a series of problems:

A. How great a pressure is involved in serious blowouts? Can they be controlled with mud?

B. On the basis of foreign experience with geothermal wells and well suppression, a method of pressurized cold water control of blowouts has been published; why can this be successfully used on some wells at the Yangbajing field but not on others? How should the well pressurizing method be chosen at the Yangbajing field?

C. Why cannot the length of the uncased bottom section be too long, particularly in a shallow section, without the danger of gushing above and infiltration below. How should the position of the casing point be chosen?

D. How should the mud specific gravity be chosen in order to control the pressure inside the well and prevent both blowouts and infiltration?

E. Why do some wells gush naturally after completion, while others must be subjected to gas lift or some other special method to induce gushing? Why is the pressurized cold water method of inducing flow which is used extensively abroad not applicable to some wells at the Yangbajing field?

Although these engineering problems differ from each other, they are all constrained by a common factor, namely stratigraphic pressure and the pressure gradient.

The problem of stratigraphic pressure and pressure gradients is a serious one which urgently requires solution. It has long received serious attention in the petroleum and natural gas well drilling world, and many methods for prediction before or during drilling have been developed,[1] such as the seismic method, which uses data on the propagation of manmade seismic waves, the sonic logging and inductance logging methods based on logging data from wells with known characteristics, the d-coefficient method which uses engineering data from the drilling of the well, and the like. In addition, on the basis of the conditions of formation and accumulation of oil and gas reservoirs, strata have been classified as high-pressure, normal-pressure and low-pressure types. The methods and the classification have reference value for the drilling of oil and gas wells, but because the stratification, heat reservoir characteristics and reservoir structure of geothermal fields differ widely from those of oil and gas strata and reservoirs, oil and gas well stratigraphic pressure classification and prediction methods are basically inapplicable to geothermal wells. To date no one in this country or abroad has attempted a classification or calculation of stratigraphic pressure in geothermal wells. We have published an article[2] providing a simple introduction to stratigraphic pressure gradients in geothermal fields as one of the problems of geothermal well drilling technology. The present article will supplement and extend the previous one. Because of limited space, certain mathematical manipulations and universally known concepts are omitted. Interested readers may consult another article in the collection from the Second Technical Conference of the Prospecting Engineering Committee of the China Geological Society.[3]

2. Classification of Stratigraphic Pressure Gradients

In order to clarify the pressure-bearing states of strata in a way that is helpful in choosing the proper engineering approach, we must analyze the data in terms of pressure. Because stratigraphic pressure gradients are closely related to engineering questions, to the sedimentary environments of strata and to later compaction or pressure release effects, the stratigraphic pressure classifications are all based on the magnitude of the stratigraphic pressure gradient.

In oil or gas wells, strata are generally classified as high, normal or low pressure types on the basis of whether or not there have been subsequent compaction or pressure leakage effects.

In high-pressure strata, the pressure gradient is from more than 0.107 to 0.23 kg/cm^2-m;

in normal-pressure strata the pressure gradient is from 0.10 to 0.107 kg/cm^2-m;

in low-pressure strata the pressure gradient is from 0.092 to 0.055 kg/cm^2-m.

With the original sedimentary state unchanged, strata which have not been tightly sealed and compacted or had pressure leakage are normal-pressure strata; because the pressure gradient of fresh water is 0.10 kg/cm^2-m and that of sea water is 0.107 kg/cm^2-m, in fresh water facies (lacustrine) or sea water facies (marine) sedimentary strata the pressure gradient of a normal-pressure stratum should be between the gradients of fresh water and sea water, i.e., between 0.10 and 0.107 kg/cm^2-m.

Stratigraphic pressure gradients higher or lower than those of normal-pressure strata are the result of subsequent sealing and compaction or pressure leakage and migration. The upper limit of the stratigraphic gradient in high-pressure strata, which is 0.23, is determined from the cap rock pressure gradient. For loose, unconsolidated strata, the cap rock pressure gradient is equivalent to the maximum internal pressure that can be borne by the stratum. If it exceeds 0.23, there is a danger of forcing through the cap rock. This is why 0.23 is defined as the upper limit; the numerical value is obtained by calculation.

The factors and strata producing thermal reservoirs are different from those producing oil and gas reservoirs. Geothermal reservoirs are usually associated with volcanic rock, and the reservoir structure is generally of an open type. The cause of formation of hot fluid is that cold surface water penetrates underground through cracks, and after heat exchange with deeply buried hot rock bodies, it rises again through structural cracks to some shallowly-buried porous or fissured stratum, where part may still pass to the surface and be lost. This type of system is an open system, and there is no question of later compaction. Accordingly, the stratigraphic pressure classification method based on subsequent compaction effects which is used for oil wells has no theoretical or real meaning for geothermal wells.

However, geothermal reservoir strata actually do have different pressure states. The deciding factor is not subsequent compaction, but rather the temperature of the reservoir and the depth at which it is located. High pressures can occur particularly in shallowly-buried reservoirs. More deeply buried ones are generally of normal or low pressure.

On the basis of blowout control and infiltration prevention characteristics of geothermal wells, we can make the classification of geothermal well strata shown in Table 1.

Table 1. Stratigraphic Pressure Classification of Geothermal Strata

Stratigraphic pressure category	Stratigraphic pressure gradient (kg/cm^2-m)	Well construction characteristics
High pressure	Over 0.12 to 0.23	Heavy mud; blowout prevention equipment; easy spontaneous gushing
Normal pressure	0.10 to 0.12	Plain water or nonheavy mud; blowout prevention equipment; easy spontaneous gushing
Low pressure	More than 0, less than 0.10	Foam or air, or use water with alternate infiltration and drilling
No pressure	Zero or less	Foam or air, or water with alternate infiltration and drilling; permanent stoppage

When the pressure balancing well-drilling method is used, Table 2-1 can be used for suitable selection of drilling fluids, including the following series of drilling fluids of different specific gravities: heavy mud → light mud → plain water → foam (air dispersed in water) → fog (water vapor dispersed in air) → air. These fluids can be used in the range between high-pressure strata with gradients of 0.23 down to zero-pressure strata with gradients of zero. If we use powdered galena as a specific gravity increaser, the fluid can even be used in super-high-pressure strata with pressure gradients as high as 0.33-0.36. But such strata have not yet been found in geothermal fields, and are quite rare even in oil and gas wells.

3. The t(Z) Function Relating Stratum Temperature and Depth

We discuss below the fact that in hot water depth-averaged specific gravity calculations and stratigraphic pressure and pressure gradient calculations we must understand the law governing the variation of stratum temperature with depth; we call this law the function $t(Z)$:

$$t = t(Z) \tag{3-1}$$

where Z is the depth and t is the stratum temperature. The derivative dt/dZ is the stratum temperature gradient.

Because of the complexity of subterranean conditions, the function t(Z) has many forms. Here, on the basis of moist-steam type geothermal fields we can make an analysis of possible forms of the function t(Z) in terms of heat transfer theory and propose some approximate calculation methods.

According to heat transfer theory, heat transfer is limited to three types: radiation, convection and conduction. Each type has its own particular conditions. Radiative heat transfer requires a relatively high heat source temperature to reach any substantial level, while thermal reservoirs are generally at rather low temperatures, usually not exceeding 200-300°, so that radiative transfer can be ignored in comparison with the other two types of heat transfer. Convective heat transfer requires the presence of a fluid, and the transfer process is accompanied by mass displacement. Accordingly, this type of heat transfer exists only in water-containing strata or heat reservoir strata. Conductive heat transfer relies on the thermal motion of molecules of solid matter, and it does not require transfer of mass. Accordingly, theoretically this type of heat transfer should exist in any type of stratum, but because rocks and strata are poor conductors of heat, the heat transfer coefficient is very low, so that in water-containing strata the effect of conduction can be neglected in comparison with that of convection, while in nonwater-containing strata or cover layers, because the effect of convection is very small, the effect of conduction cannot be neglected, and it is the main heat transfer type in nonwater-containing strata.

Thus, on the basis of the heat transfer characteristics of strata we can very roughly classify geothermal field strata as convective or conductive. The former type are water-containing layers, such as heat reservoirs and cold-water-containing strata. The latter are nonwater-containing strata such as the cap rock, water-enclosing strata of thermal reservoirs and other nonwater-containing strata. Below we discuss the thermal gradient characteristics and t(Z) function for these two types of strata.

A. Conductive Strata

The decline of geothermal flow with time is very slow, and accordingly for heat conduction we can use the Fourier equation for stable heat flow:

$$q = \frac{\lambda}{Z - Z_0} (t - t_0) \tag{3-2}$$

Rewriting this formula and letting

$$K = \frac{q}{\lambda} \tag{3-3}$$

we obtain the formula for t(Z):

$$t = t_0 + K (Z - Z_0) \tag{3-4}$$

where q is the quantity of heat (kcal/m^2-hr) flowing through 1 square meter of surface in an hour. Because this is stable heat flow, and relative to the well segment $Z - Z_0$ for which the calculation is being performed the heat reservoir area is very large, so that the area through which heat flows between Z_0 and Z can be considered approximately constant, we can assume that q is approximately constant; λ is the conductivity of the stratum (kcal/m·hr·deg), and for strata at the same level we can consider it to be constant. K is the stratigraphic thermal gradient (°C/meter), t_0 and t are the temperatures (°C) of a known point and the calculation point; Z_0 and Z are the depth of the known point and the calculation point (meters).

For a specific stratum we can consider q and λ to be approximately constant, so that K is also a constant. Accordingly formula (3-1)a is a straight line function.

Because the conductivity λ of rock is very small and the unit heat flux q is much larger than for an ordinary stratum, the temperature gradient K of the cap rock is rather large. A high temperature gradient is a characteristic of cap rock.

B. Convective Strata

The pores and fissures in convective strata are full of fluid. In general, because of the natural convection of hot water, the upper and lower parts of a given stratum have rather uniform temperature, which is to say that the temperature gradient $K = dt/dZ$ approaches zero. This is the general characteristic of convective strata.

The function t(Z) is a straight line function:

$$t = \text{const.} \qquad (3\text{-}1)\text{b}$$

However, when there is entering cold water, the temperature law for the transition zone in which cold water and hot water are in contact is relatively complex. It is affected not only by the position of entry of the cold water and the runoff flow rate, but also by the degree of fissuring of the stratum, and it is difficult to propose a precise and general formula: we can only use approximate methods. We used a trapezoidal approximation approach, using the straight-line function (3-1)a to give approximately the function t(Z) for the transitional zone. This may involve a rather large error in the transition zone, but because its thickness is much less than the depth of the well, the error can be neglected in engineering calculations regarding depth-averaged specific gravity and stratigraphic temperature gradient.

To sum up the foregoing, for both conductive and convective layers the function t(Z) of a simple stratum can be expressed by the formula

$$t = t_0 + K\ (Z - Z_0) \qquad (3\text{-}1)\text{a}$$

For conductive cap rock and convective transitional zones, K will be rather large and will be positive for temperature increasing with depth and negative for decreasing temperature; for most reservoirs K is close to zero.

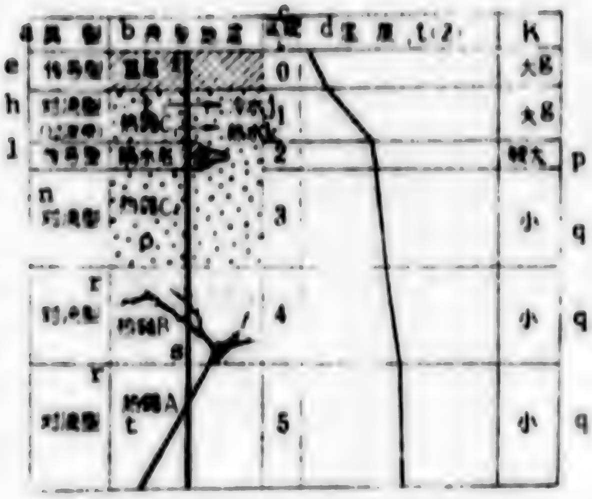

Figure 1. The different characteristics of the function t(Z) and the pressure gradient K indicate that: reservoir C_1 is affected by cold water runoff and is a transition zone; collector C_2 is not affected by cold water runoff or is only slightly affected; C_1 and C_2 are both gravel reservoirs; reservoir B is a silica sandstone reservoir; and reservoir A is a deep fissured reservoir.

Key:

a. category
b. typical stratum
c. zone number
d. temperature, t(Z)
e. conductive
f. cover layer
g. large
h. convective (transition zone)
i. Reservoir C_1
j. cold water
k. hot water
l. conductive
m. water-impermeable stratum
n. convective
o. Reservoir C_2
p. relatively large
q. small
r. convective
s. Reservoir B
t. Reservoir A

Figure 1 shows the characteristics of the function t(Z) and the thermal gradient for typical strata. The graph of these characteristics is useful when using well temperature data to determine the true temperature of the heat reservoir. Because the temperature curve for the well interior reflects the temperature of the fluid in the well (and not that in the stratum), if no analysis is made and the well temperature is taken as the reservoir temperature, the error may be very large. If in the reservoir section of the well effects are produced by cyclic cooling by the mud and vertical heat convection, the temperature inside the well or the temperature of the stratum near the well wall will be lower than the true temperature of the heat reservoir; moreover, in a well section in a layer impermeable to water or in a cover stratum, owing to gushing or vertical heat convection, the temperature inside the well may be much greater than the true temperature of the stratum itself, a phenomenon which is especially apparent in the section near the reservoir. Accordingly, in order to minimize the difference between temperature measurement data and the reservoir temperature, before taking temperature readings there must be a thorough purging (generally at least 24 hours), and the temperature must be read immediately after closing off the well. Moreover, for fissured reservoirs, temperature data in the fissured area is the best indication of the true reservoir temperature.

4. The Relationship Between the Specific Gravity and Temperature of Water

The formula expressing the relationship between the specific gravity and the temperature of pure water can be obtained from saturated steam tables.[4] For convenience in calculating stratigraphic temperature gradient formulas, we use an approximate calculating formula:

$$r_W' = 1.020 - 0.040 \cdot 10^{-2}t = 0.020 \cdot 10^{-4}t^2 \qquad (4\text{-}1)$$

where t is the temperature (°C) and r_W' is the specific gravity of pure water.

The relative error ε of approximate formula (4-1) is:

not greater than 1.10 percent when t = 40-300°C;
not greater than 0.6 percent when t = 10-280°C;
not greater than 0.35 percent when t = 80-200°C.

These errors have no effect at all on engineering calculations of the stratigraphic pressure gradient.

A real geothermal fluid will contain large quantities of soluble minerals and suspended microscopic particles, and accordingly the specific gravity will be greater than for pure water. In the thermal fluid of the Yangbajing Geothermal Field the level of dissolved minerals is rather low, and the increase in specific gravity resulting from the solid phase can be taken as 0.01 - 0.02. In blowout prevention calculations, we generally use the higher value (0.02). Accordingly, the specific gravity of the thermal fluid in the Yangbajing field is:

$$r_W = 1.04 - 0.04 \times 10^{-2}t - 0.02 \times 10^{-4}t^2 \qquad (4\text{-}2)$$

5. The Stratigraphic Pressure Gradient as a Function of Depth in the Yangbajing Field

Here we only discuss the pressure gradient laws for a liquid within the reservoir. According to Figure 2, when the differential increase corresponding to any well depth is dZ, the increase in the stratigraphic pressure is:

$$dP = 0.1r_W \cdot dZ \qquad (5\text{-}1)$$

key: a. stratigraphic pressure P
b. depth Z

Figure 2. Stratigraphic pressure calculation chart

According to formula (3-1)a, we obtain dZ = 1/Kdt. We then substitute the values from equation (4-2). After integration and application of the following initial conditions:

$$t = t_0 \text{ and } P = P_0 \text{ when } Z = Z_0,$$

we obtain the following integral formula:

$$\frac{10(P-P_0)}{Z - Z_0} = 1.04 - 0.04 \times \frac{t_0 + t}{2} \times 10^{-2} - 0.02 \times \frac{t_0^2 + t_0 t + t^2}{3} \times 10^{-4} \qquad (5\text{-}2)$$

It can be shown that when the temperature t_0 inside the well is between 120° and 370°C, the calculation error resulting from replacement of the term $\frac{t^2 + t_0 t + t^2}{3}$ in formula (5-2) by $\left(\frac{t_0 + t}{2}\right)^2$ is less than 0.5 percent. Then, letting

$$T = \frac{t_0 + t}{2} \times 10^{-2} \qquad (5\text{-}3)$$

we can simplify formula (5-2) to:

$$\frac{10(P - P_0)}{Z - Z_0} = 1.04 - 0.04T - 0.02\,T^2 \qquad (5\text{-}2)a$$

The term $\frac{10(P - P_0)}{Z - Z_0}$ on the left side of formula (5-2) is actually the specific gravity averaged over depth of the hot water in the well section between Z_0 and Z, and if we replace it by r_{Wa}:

$$r_{Wa} = \frac{10(P - P_0)}{Z - Z_0} \qquad (5\text{-}4)$$

then $$r_{Wa} = 1.04 - 0.04T = 0.02T^2 \qquad (5\text{-}5)$$

In order to derive the stratigraphic pressure P at depth Z, we have only to convert equation (5-4):

$$P = 0.1\,[(10P_0 - r_{Wa}Z_0) + r_{Wa}Z].$$

if we let: $$\Delta H = 10\,P_0\,r_{Wa}Z_0 \qquad (5\text{-}6)$$

then $$P = 0.1\,(\Delta H + r_{Wa}Z) \qquad (5\text{-}7)$$

In the above formulas, P_0 is the stratigraphic pressure (kg/cm^2) within the reservoir at the known depth Z_0 (meters); Z_0 is the depth of the known point (meters); P is the stratigraphic pressure at the calculation point Z (kg/cm^2); Z is the depth of the calculation point (meters); ΔH_0 is the pressure constant (in meters of a water column); r_{Wa} is the specific gravity averaged over depth of the hot water between dephts Z_0 and Z of the well section in the reservoir; and T is 1/100 the average temperature in the well section from Z_0 to Z.

Below, we discuss the depth-averaged specific gravity r_{Wa} and the pressure constant ΔH_0 of formula (5-7).

A. The Depth-Averaged Specific Gravity

We can see from equation (5-5) that the depth-averaged specific gravity between Z_0 and Z is related only to the average temperature divided by 100 in that section. We know from the discussion of the function t(Z) that for most reservoirs (convective strata), t is almost invariant with depth (with the exception only of transition zones which cold water is entering), and accordingly there is no necessary connection between the depth-averaged specific gravity and the depth. It is very important to recognize this fact, because it can greatly simplify the calculation of the depth-averaged specific gravity.

The above discussion was for single-stratum conditions. If one well passes through several reservoirs with different temperature gradients K or different temperatures, as in Figure 1, and if the known point Z_0 and the calculation point Z are in different reservoirs, we must first use equation (5-5) to find the depth-averaged specific gravities for the individual sections separately, before we can derive the average value.

It should be pointed out that for ordinary cold water wells, the calculation is much simpler, since we can take r_{Wa} equal to 1.0.

B. The Pressure Constant

The physical significance of the pressure constant can be seen from formula (5-6) and Figure 3. It is equivalent to the height of the pressure head above the surface of the wellhead. This is a very useful constant which gives a well's pressure-bearing state.

The pressure constant is almost independent of well depth, and accordingly using it to describe the pressure-bearing state of a well is more universal than using the stratigraphic pressure or the pressure gradient, because separated from well depth conditions the latter two quantities are meaningless.

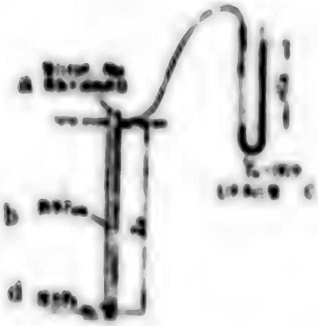

Figure 3. Physical significance of the pressure constant ΔH_0. A tube filled with hot water of average specific gravity r_{wa} and its top sealed simulates a well with closed wellhead. The height to which the fluid in the manometer (specific gravity 1) rises (height of pressure head) is equivalent to the pressure constant ΔH_0.

Key:

a. tube opening sealed; simulates well with closed wellhead
b. hot water (r_{wa})
c. U-tube manometer, water with $r_w = 1$
d. pressure P_0

The depth-averaged specific gravity and pressure constants for certain wells in shallow reservoirs in the Yangbajing field are shown in Table 2.

Table 2. Pressure Parameters of Some Wells in the Yangbajing Field

[illegible] A	[illegible] b	[illegible] h, [illegible] c	[illegible] γ_{wa} d	[illegible] ΔH_0, [illegible] e	[illegible] Δh_0, [illegible] f	[illegible] h_0 [illegible] g	[illegible] h
1	41	4283.2	0.95	7.0	7.37	4290.6	[illegible] i
2	71.85	4284.7	0.93	8.9	9.57	4294.3	[illegible] i
3	111.21	4283.8	0.95	6.0	6.32	4290.2	[illegible] i
4	88.42	4281.8	0.97	9.2	9.49	4291.3	
5	457.20	4297.2	0.96	7.9	8.23	4305.4	
6 A	554.70	4284.1	0.92	24.1	26.2	4310.3	
7	602.70	4279.7	0.95	17.0	17.9	4297.6	
9	87.35	4298.8	0.90	14.8	16.5	4315.3	
13	200.54	4333.7	0.92	−16.7	−18.1	4315.6	

Key:

a. well number
b. depth, meters
c. wellhead elevation above sea level h, meters
d. depth-averaged specific gravity of hot water, γ_{wa}
e. pressure constant ΔH_0, meters of water column
f. excess altitude of zero-pressure point Δh_0, meters
g. zero-pressure point elevation above sea level h_0, meters
h. remarks
i. estimated

Methods of determining the location of the pressure constant:

One of the methods given below can be used to determine the pressure constant ΔH_0; the methods can be used for determinations under different circumstances. It is best to make determinations using several methods for mutual verification.

(1) Actual Pressure Determination Method

After a well which has been thoroughly blown out is closed, a downhole manometer is used at some depth Z_0 inside the reservoir to determine the pressure P_0 inside the wel , after which the calculation is made with equation (5-6).

It must be pointed out that only pressure determinations made inside the reservoir can be used for this calculation. To make the reading be as close as possible to the real pressure, it is best to lower the pressure sensor to a location where the fluid passages are relatively good, for example a porous stratum with rather large fissures or permeability.

(2) Balancing Mud Density Method

When balancing occurs in the well drilling process, the specific gravity of the drilling mud can be finely adjusted so that the pressure of the mud column and the stratigraphic pressure balance each other; the mud specific gravity r_0 at the time of equilibrium and the bubbling or infiltration location Z_0 are recorded, and the pressure constant is calculated according to the following formula:

$$\Delta H_0 = (r_0 - r_{Wa})\, Z_0 \qquad \text{(5-6)a}$$

(3) Wellhead Back Pressure Method

When the location of a bubbling of infiltration stratum cannot be determined, this method may be used. This method too is used when the pressure coefficient ΔH_0 is positive. It can be used to determine simultaneously the position Z_0 of bubbling or infiltration and the stratigraphic pressure P_0.

The well is pressurized with two kinds of muds with specific gravities r_1 and r_2 which are both lower than that required to balance the stratigraphic pressure, and the casing pressures P_{C1} and P_{C2} for the closed well are determined separately, after which P_0 and Z_0 are calculated by the following formulas:

since $\qquad P_0 = P_{C1} + 0.1\, r_1 Z_0$

and $\qquad P_0 = P_{C2} + 0.1\, r_2 Z_0$

accordingly,

$$Z_0 = \frac{10(P_{C1} - P_{C2})}{r_2 - r_1} \qquad \text{(5-8)}$$

By substituting Z_0 into any one of the formulas above, P_0 can be obtained. The value of ΔH_0 is then calculated by formula (5-6) using the values of Z_0 and P_0.

(4) Water Level Depth Method

This method is used when there is a low pressure gradient, i.e., when the pressure constant ΔH_0 is negative.

Cold water is introduced into the well, and the static water level Z_1 is determined, after which the stratigraphic pressure P_0 can be calculated from the following formula:

$$P_0 = 0.1\, r_w (Z_0 - Z_1) \tag{5-9}$$

where $r_w = 1$, the specific gravity of the cold water. The value of ΔH_0 can be calculated from equation (5-6) using Z_0 and P_0.

If the water infiltration level Z_0 cannot be determined, two thin muds (specific gravity not greater than 1.10) with different specific gravities r_1 and r_2, or plain water, can be introduced into the well, and the static level Z_1 and Z_0 determined, after which Z_0 can be calculated from equation (5-10):

since $$P_0 = 0.1\, r_1(Z_0 - Z_1)$$

and $$P_0 = 0.1\, r_2(Z_0 - Z_2)$$

accordingly $$Z_0 = \frac{r_1 Z_1 - r_2 Z_2}{r_1 - r_2} \tag{5-10}$$

It is easy to find P_0 from Z_0, after which ΔH_0 can be found from equation (5-6).

Below we derive formulas for the stratigraphic pressure gradient and the equivalent specific gravity.

If we substitute the value of P from equation (5-7) into the pressure gradient formula and the equivalent specific gravity formula, we obtain:

$$G = 0.1 \left(r_{Wa} + \frac{\Delta H_0}{Z} \right) \tag{5-11}$$

and $$r_b = r_{Wa} + \frac{\Delta H_0}{Z} \tag{t-12}$$

where G is the geothermal pressure gradient and r_b is the stratigraphic pressure equivalent specific gravity. Moreover, $r_b = 10G$. G and r_b have similar forms, and accordingly because of limited space we will discuss only r_b.

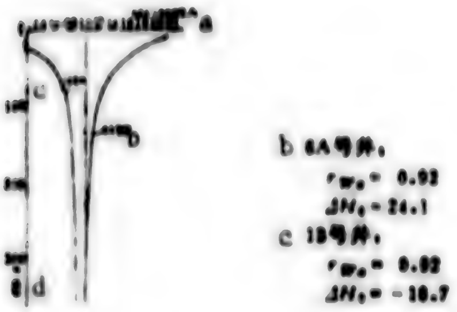

Figure 4. Curves of rh(Z) for wells 6A and 13, Yangbajing field

Key:

a. (illegible)	c. Well 13
b. Well 6A	d. depth, meters

The curve for the stratigraphic pressure equivalent specific gravity for wells Nos 6A and 13 of the Yangbajing field, determined from equation (5-12), are shown in Figure 4. Well 6A is a well with a positive pressure constant, and well 13 has a negative pressure constant. The curves for the two wells have different directions of curvature.

6. The Surface Patterns of the Stratigraphic Pressure Gradient and the Zero-Pressure Surface Contour Map for the Yangbajing Field

When choosing a well drilling process for new well sites and determining the surface distribution of the reservoir, it is necessary to understand the variation of the pressure gradient over the surface coordinates of the well locations, i.e., the surface distribution law.

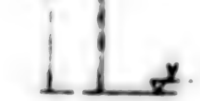

Figure 5. Relationship of depth coordinate to elevation coordinate

For ease in comparing the parameters for different well locations, here we use the elevation above sea level instead of the depth as previously. If we let the elevation be y at a location with depth Z, the wellhead elevation is h, as in Figure 5, we obtain:

$$Z = h - y \tag{6-1}$$

and substituting into equation (5-7) we obtain

$$P = 0.1\ [\Delta H_0 + r_{Wa}(h - y)] \tag{6-2}$$

According to equation (6-2) there must exist some elevation above sea level h_0 at which the stratigraphic pressure P is equal to zero: $y = h_0$, $P = 0$; substituting into equation (6-2) we obtain

$$h_0 = h + \frac{\Delta H_0}{r_{Wa}} \tag{6-3}$$

and if we let $$\Delta h_0 = ho - h \tag{6-4}$$

we obtain $$\Delta h_0 = \frac{\Delta H_0}{r_{Wa}} \tag{6-5}$$

where h_0 is the elevation in meters at the zero-pressure point, and Δh_0 is the difference in elevation between the zero-pressure point and the wellhead topography, and is called the excess altitude of the zero point.

The sea level elevation h_0 of the zero-pressure point indicates the magnitude of the potential energy of the fluid; the excess altitude of the zero-pressure point Δh_0 is similar to the pressure constant ΔH_0 in giving a well's pressure bearing characteristics, but ΔH_0 is in pressure units expressed as the height of a water column, while Δh_0 is in geometric units. The value of h_0 is determined only by reservoir characteristics, while ΔH_0 and Δh_0 are related not only to reservoir characteristics but also to the terrain elevation. With identical h_0F, the greater the elevation of the wellhead, the smaller ΔH_0 and Δh_0, which completely explains why wells drilled in the northern part of the Yangbajing field are likely to infiltrate, while in the southern part they are likely to gush.

By connecting a series of zero-pressure points we can form a zero-pressure surface. In order to express this zero-pressure surface on a flat diagram, we use the contour method, and call a map of this kind a zero-pressure contour map. Figure 6 is a zero-pressure contour map for shallow reservoirs in the Yangbajing field based on the zero-pressure point elevations of existing wells.

The characteristics of some of the wells in the Yangbajing field are shown in Table 2.

Below we given an example to explain the use of the zero-pressure contour map.

If the surface position and wellhead altitude of well B which is about to be drilled is h = 4288 meters (see Figure 6), determine the specific gravity of the mud needed to balance the stratigraphic pressure in that well.

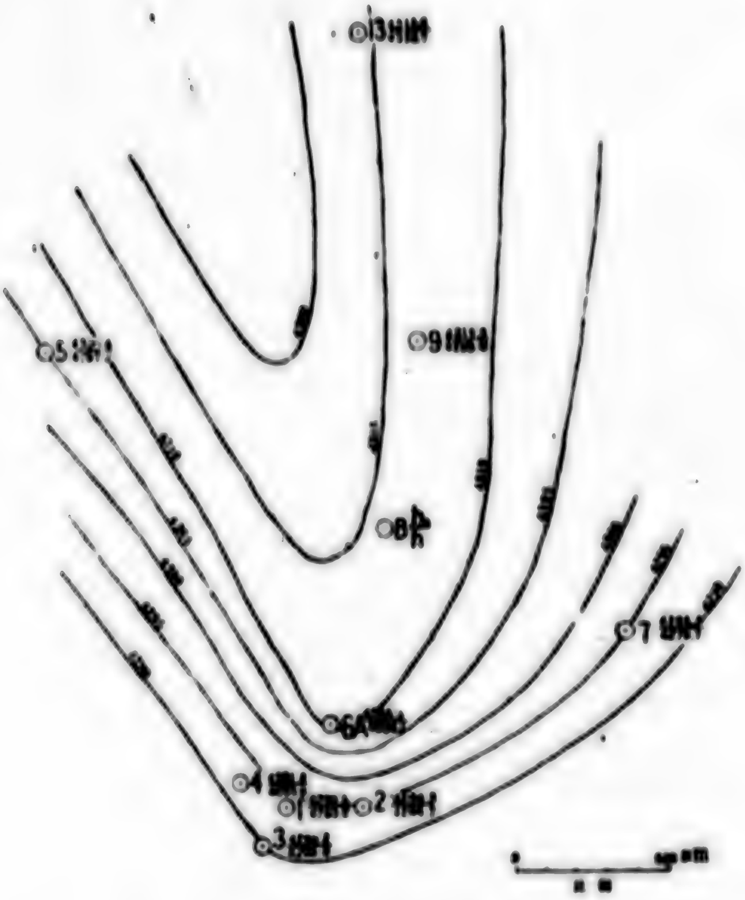

Figure 6. Zero-pressure surface contours for shallow reservoirs on Yangbajing field

Key: Large number beside well symbol is well number, numerator is zero-pressure point elevation, denominator is wellhead elevation.

Answer: First we show the surface coordinates position of well B on the zero-pressure map (Figure 6), and read from the map the zero-pressure altitude h_0, which is 4314 meters. Thus the excess elevation of the zero-pressure point is $\Delta h_0 = h_0 - h = 26$ meters.

On the basis of temperature data from well B, we can use formula (5-5) to calculate the depth-averaged specific gravity r_{Wa}. If the temperature is unknown, we can determine it approximately from the known depth-averaged specific gravities of wells in the vicinity of well B (such as 6A and 9), obtaining $r_{Wa} = 0.92$.

We obtain the pressure constant from equation (6-5): $\Delta H_0 = r_{Wa} \cdot \Delta h_0 = 29.9$ meters water column. From equation (5-12), the relationship of the stratigraphic pressure equivalent specific gravity r_b and the depth for well B is:

$$r_b = r_{Wa} + \frac{\Delta H_0}{Z} = 0.92 + \frac{23.9}{Z}$$

In order to prevent gushing, the correct mud specific gravity r_m should be greater than r_b 0.02 - 0.04; if we choose 0.02, then

$$r_m = 0.94 + \frac{23.9}{Z}$$

We can see from this equation that the specific gravity of the mud should be gradually decreased as the well becomes deeper. The maximum specific gravity is determined by the depth at which the top of the shallow reservoir is located; for example, if the depth of the reservoir Z is 30 meters, then the specific gravity of the mud used at the beginning of drilling should be:

$$r_m = 0.94 + \frac{23.9}{Z} = 1.74$$

7. Use in the Drilling Process

Here we will give a simple description of the use of the pressure gradient law in the problems described in section 1; a complete description is not the purpose of the present article.

A. Estimation of the Pressure Bearing State of the Shallow Reservoirs in the Yangbajing Field

A high-pressure constant indicates that the well is likely to gush, while in the reverse case it is likely to infiltrate. Accordingly, the potential for gushing (or infiltration) can be quantitatively estimated by means of the pressure constant ΔH_0. We can see from Table 2 and Figure 6 that the value of ΔH_0 for the southeast portion of the field is higher than that for the northwest part, and on the mountain slope north of Zhongni Highway ΔH_0 even becomes negative. Accordingly, wells drilled in the southeastern section are likely to gush, while those drilled in the northwestern section are likely to infiltrate; in addition, we can also see that in the vicinity of a line connecting wells 2 and 6A, the pressure constant is rather high, and the farther away to the side one moves from the line between, the lower ΔH_0 becomes.

The area with high pressure constant values is in the vicinity of well 6A, and the maximum value is 24.1 meters (water column). On the basis of this datum, we are justified in believing that the stable wellhead pressure value for wells drilled into the shallow reservoirs in the Yangbajing field that have been closed cannot exceed 2.5 kg/cm^2. It is easy to calculate from equation (5-12) that for these wells (with a reservoir depth Z generally about 30 meters), we can control the stratigraphic pressure with a mud with a specific gravity of about 1.75 and prevent gushing. This completely answers the first question that was posed in section 1. Actual results have corroborated this conclusion.

B. Selection of Well Suppression Method

Geothermal wells have a rather high temperature, and the literature of many countries has reported the use of pressurized cold water cooling as a means of controlling gushing. This method was also used in the initial period of drilling in Yangbajing. But under many conditions the method was ineffective. Analysis and calculations of the stratigraphic pressure gradient helped us to understand the essence of the phenomenon. We believe that the essence of cold water control depends on whether or not the pressure gradient of the cold water column can exceed the stratigraphic pressure gradient. This means that only when the stratigraphic pressure gradient equivalent specific gravity is less than the specific gravity of cold water can the pressurized cold water method achieve results. Otherwise, it is necessary to use the mud well suppression method or stay with the drill rod suppression method or the capping suppression method.

Here we must point out that gushing and infiltration are two expressions of the same essence: the former is violent and the latter gradual. In general when the wellhead excess pressure is maintained below 0.5 kg/cm^2 it is the latter form that occurs. For some wells with rather low pressure constants (but larger than zero), if a sufficient amount of continuous cold water injection is used to maintain the liquid column pressure steady, a relatively low wellhead excess pressure can be maintained in a constant state, at which time the goal of prolonged bubbling but no gushing can be achieved. But this "well suppression" is incomplete.

C. Selection of the Length of the Uncased Bottom Hole and the Position of the Casing Point

We can see from formula 5-12 that when the pressure constant ΔH_0 is positive, the stratigraphic pressure equivalent specific gravity r_b decreases hyperbolically as the depth Z increases. The shallower the well, the more rapidly it drops off. Accordingly, when the length of the uncased bottom hole is too great, the difference in the mud specific gravities required at the two ends of the uncased section is increased, with a high specific gravity required at the top and a low specific gravity required at the bottom, so that it is difficult to use a mud with one specific gravity to satisfy the two different requirements. This is the reason why geothermal wells are extremely likely to show upward gushing above and downward infiltration below. This phenomenon is even more pronounced when drilling into shallow strata. The method of overcoming it is to select the location to which the casing penetrates in accordance with the infiltration suppression pressure gradient and the stratigraphic pressure gradient, to control the length of the uncased bottom hole, and at the same time to use an infiltration plugging method. In addition, the mud specific gravity should be correctly calculated for different depths.

D. Selection of a Method of Inducing Gushing

The pressure gradient data are straightforward indications of the degree of difficulty of inducing gushing of a well after it has been completed. Wells with a pressure gradient greater than 0.1 can conveniently be induced to gush by decreasing the mud specific gravity; those with a gradient less than 0.1 can only be induced to gush by gas lift or pumping of water. Some wells in which the pressure gradient is close to that of plain water can be induced to gush by the "heating effect," which consists of introducing plain water and waiting for it to become heated, when its specific gravity will decrease, thus inducing gushing. The stratigraphic pressure gradient data are very useful in selecting and calculating the above flow-inducing methods.

In other countries the heating effect method after introduction of cold water is extensively used for high temperature geothermal wells with temperatures between 200° and 300°. But it must be seriously pointed out that this method is generally useless for certain negative-pressure-constant wells with a temperature below 200° and with cold water runoff in the shallowly buried section. Under these latter circumstances, the saturation pressure of the hot fluid is rather low, and there is no way of overcoming the pressure of the water column (with a rather low temperature) in the well.

E. Selecting the Drilling Fluid

In order to control gushing, prevent infiltration, and also to prevent the reservoir from becoming clogged, the best approach is to use the pressure balancing method of drilling. The stratigraphic pressure gradient data are useful in selecting the kind of drilling fluid to be used. In general, when the stratigraphic pressure equivalent specific gravity is equal to or greater than the specific gravity of plain water, plain water or a drilling fluid of the appropriate specific gravity can be used to drill the well, but when the equivalent specific gravity is less than that of plain water, foam, fog or air can be selected for drilling, depending on the magnitude of the equivalent specific gravity. The low specific gravity fluid method of well drilling is promising for wells in the northwestern part of the Yangbajing field and in wells whose deeper sections have low pressure gradients.

8. Conclusions

A. The stratigraphic classification used for oil or gas wells should not be used to classify strata of geothermal fields. This article proposes an approach to pressure classification.

B. The relationship between the stratigraphic pressure gradient of a geothermal field and depth can be described by a hyperbolic function. In the shallow section, the parabolic curve changes steeply, while in the deep section it slopes more gently. Accordingly particular care must be taken when drilling into shallow reservoirs.

C. The direction of curvature for wells with positive and negative pressure coefficients are opposite, but they all have the depth-averaged specific gravity of the heat fluid as their limit.

D. A method of drawing a zero-pressure surface contour map is proposed. It is helpful in estimating the stratigraphic pressure gradient situation at different surface positions.

Afterword

Although this article is intended to apply to high-temperature moist steam geothermal fields, its principles are also applicable to hot spring wells, cold water wells, exploratory drilling in solid mines and other engineering drilling exploration. Under these conditions, because the temperature is rather low, (for the most part normal) the depth-averaged specific gravity of water r_{Wa} can be taken as 1.0, so that the various calculations become much simpler.

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APPLIED SCIENCES

HAJIF-1 AIRCRAFT STRUCTURAL ANALYSIS SYSTEM DESCRIBED

Beijing GUOJI HANGKONG [INTERNATIONAL AVIATION] in Chinese No 2, 5 Feb 80 pp 2-4

[Article by Aircraft Structural Analysis System Development Group: "Brief Introduction to the HAJIF-1 Aircraft Structural Analysis System"]

[Text] The HAJIF-1 (Hangkong Jiegou Fenxi Xitong 1) Aircraft Structural Analysis System is a large-scale general-use set of finite element structural analysis computer programs independently developed by our country. A study lasting 10 months has shown the system's operation to be satisfactory, so that it is now ready for formal use.

Back in the late 1950's, our country began to use computers for stress and deformation analysis of aircraft structures. At the time, a displacement method using beams and torsion resistance boxes was used. In the early 1960's a standardized program was developed using a direct stiffness method and substructure techniques. Starting in the 1970's, the limited-element method was used to develop many specialized and general programs for use in structural analysis and summarization. In 1976, the China Aviation Research Institute (CAE) decided to bring together groups belonging to four of its research institutes in a special development group in order to begin development of a large-scale general structural analysis system; it started by developing the HAJIF-1 linear static analysis section.

Design Approach

In order to make the new system easier to use, more efficient and broader in application than previous structural analysis programs, the development work concentrated on automatic generation of starting data, a special user-oriented structural analysis language, and a highly efficient, high-order sparse matrix analysis method. The specifics of the design approach include:

1. Generality of application. A multilevel substructure analysis technique was used, making it possible to analyze any type of large-scale complex structure.

2. Flexibility. We used a user-oriented structural analysis language which could carry out 15 fixed routines contained in the system and could also utilize specially-defined operations written by the user.

3. High efficiency. The system features specialized data statements and automatic generation of starting data, and offers the user two alternative solution methods.

4. Expandability and ease of revision. The system has a modular structure, so that to revise or add new capabilities it is only necessary to revise or add the relevant module, without altering any other modules.

5. Interrupt and diagnostic features. The system has an interrupt processing capability, a step-through capability, and can restart after a present interrupt is found. It has a certain error diagnosis capability, and it can emit a warning signal or stop operation depending on the nature of the error.

6. Easy machine interchangeability. With the exception of a small part of the program which is written in assembly language, the program is written in FORTRAN IV, which makes it easy to use it on computers of different types.

System Capabilities

The HAJIF-1 system can carry out linear deformation and stress analysis of thin-walled structures, crossbeam frames and framed girders under external load, and will soon have the additional capability of analyzing three-dimensional continuous elastic bodies. There are no limitations on the types of problems that can be solved. But because the computer on which it is currently being used has a relatively small memory (256 Kbyte) and is rather slow (fewer than 100,000 operations per second in double-precision floating point arithmetic), the scale of the problems is limited to a maximum of 10 substructure levels, and a maximum of 99 individual substructures, with no more than 3,000 degrees of freedom for each substructure and no more than 6 degrees of freedom for each node. The system has 30,000 FORTRAN and assembly language statements.

The system offers 15 fixed routines, including triangularization analysis, displacement, stress analysis and influence number calculation based on assembly of a stiffness matrix; triangularization analysis, displacement, stress analysis and influence number calculation based on assembly of a boundary stiffness matrix; displacement; stress calculations; influence number computation, and the like.

The system's elements store contains 18 elements including various rod elements, beam elements, plate elements, thin surface elements and rigid elements. The materials store contains 7 materials, including LY12 (plate and shaped stock), LC4 (plate and shaped stock), 30CrMnSiA, 30CrMnSiNi2A and 1Cr18Ni9Ti.

Mechanics Design of the System

The HAJIF-1 system divides the nodal degrees of freedom into five types: degrees of freedom of nodes within substructures; degrees of freedom of nodes at substructure boundaries; degrees of freedom at moving boundaries, primarily used when the generalized displacement in the direction of one degree of freedom is a fixed value; permanently fixed degrees of freedom, primarily providing constraints when eliminating motions of structural rigid bodies; and symmetrical and antisymmetrical degrees of freedom, primarily used in symmetricity treatment of structures.

The HAJIF-1 system provides five rectangular coordinate systems: substructure coordinate systems; element coordinate systems; nodal coordinates, primarily used in eliminating abnormal states arising from the formulas as a result of very low strength in the direction of one of the degrees of freedom; assembly coordinates, principally used in providing parameters for standard-geometry assemblies of structures and automatic generation of the calculation model grid; and structure coordinates, which function as common reference numbers for all of the structures.

The basic steps of the solution by HAJIF-1 are: assembly of the substructure stiffness matrix, handling of constraint elements, substructure analysis, symmetry processing, interconnection of substructures, and multilevel substructure analysis, displacement, stress computation, and influence number computation.

System Mathematical Methods

In the static analysis, triangularization analysis of the stiffness matrix occupies the largest part of computation time. Accordingly the efficiency of the high-level sparse matrix solution method very strongly affects system efficiency. HAJIF-1 offers two solution methods which can handle sparse matrices of any width and are very efficient.

1. Automatic partitioning and effective column solution method, which uses two techniques to make it efficient. It avoids all empty operations which do not change the calculation results, and minimizes intermediate multiplication and addition results in the inner cycles; and depending on the size of the work area in the computer internal memory, it divides the columns of the matrix it contains into two types: those in the partitions, which are the principal columns, and those included among the effective columns, which are those whose influences must be calculated. During each step, only the elements needed for that step are entered into memory, which decreases the number of transfers between internal and external memory.

2. The superelement matrix analysis method, which simultaneously divides the stiffness matrix into many original level submatrices, and arranges these submatrices on the basis of their corresponding positions in the stiffness matrix so as to achieve a two-level direct-indexed matrix. If the order of the second-level address-indexed matrix is still too high, it can be further divided using the above method to obtain third-level addressed indices. This data organization method is relatively well suited to third-generation computers, and makes transfer of data in internal and external memory convenient and increases efficiency.

Program Organization

The HAJIF-1 program organization is on the two-level principle (Figure 1). The first level is the system individual capability modules, which are independent of each other, and merely carry out their individually specified functions, without being able to affect each other. The second level is the supervisor program, which is used to control the various functional modules, and to control the entire calculation and analysis process. The supervisor program is resident in main memory, while the various functional models are rolled in and out.

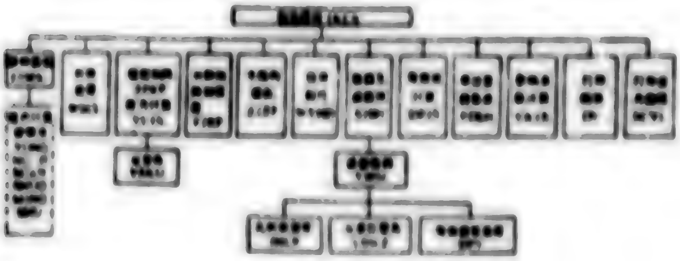

Figure 1. Overall structure of HAJIF-1

Key:

JKCX: Supervisor program
JSMK: Interpreter module
YONG HU...: User manual
WSCL: External processing
JPKP: Assemble stiffness matrix
YLJS: Stress computation
YSKU: Element store
FJKP: Analyze stiffness matrix and loads
ZJZP: Substructure assembly
WYHD: Displacement
SJSH: Data generation module
YXSJ: Initial shape data
JHLX: Geometrical shapes store
YSWZ: Element position store
DPY: Equivalent load displacement store
DPJS: Equivalent load computation
PDSH: Unit load formation
YXJS: Influence number computation
DY: Printout module
SCYL: Print stress curve

The system provides a user-oriented structural analysis language in order to adapt the multiplicity of structures and the different requirements of different users. This language consists of 92 statements which use Chinese romanization letters. The system interpreter module translates the initial program written by the user in the structural analysis language into a string of internal code which can be recognized by the system supervisor program. The supervisor program then organizes the computation process on the basis of the information contained in the internal code. In addition to the 15 above-mentioned routines provided by the system, the user also may use the structural analysis language to write his own subroutines, thereby meeting the need for flexibility.

Data Generation in the System

HAJIF-1 has a data generation module which can automatically generate the starting data, greatly simplifying the user's data preparation work. Data generation can be divided into external load calculation and structural data generation.

The task of external load computation is to assign the distributed aerodynamic forces and inertias equivalently over the structural mechanics model's nodal points and assure that the entire aircraft's external aerodynamic loads are in complete equilibrium with its inertial loads. HAJIF-1 can calculate the aerodynamic force distribution over the wings, tail and body on the basis of wind tunnel results or strength standards, can calculate the inertial force distribution, and of course can use loads specified by the operator.

The structural data generation module can, on the basis of user-specified control points and section lengths, automatically carry out a grid analysis of the standard geometric components: lines, curves, planes, curved surfaces, and form the corresponding nodal coordinates. The data generation module provides a total of 13 different geometric assembly shapes, including standard curvilinear segments, composite curvilinear segments, line segments, arc segments, parabolic segments, conic sections, parabolic sections, four-sided planar sections bounded by 4 composite curves, irregular nodal geometry component types and the like.

For element node information, the data generation model provides five element position generation statements.

For convenience in processing large quantities of data that continually reappear according to a specific pattern, the data generation model contains two constant difference data repetition statements and one data repetition statement. In summary, it can be seen that the various steps in HAJIF-1 from load calculation and structural data generation to calculation of structural deformation and stress distribution are connected into a whole, and accordingly they are convenient for the user and efficient.

An Example of System Utilization

After overall system debugging was completed, a total of 26 sample problem calculations were made. These problems ranged from small scale to large scale and from simple to complex, and finally a complete stress analysis of a certain aircraft was carried out. The entire body of the aircraft was divided into 20 substructures as shown in Figure 2. The largest substructure had 2,238 degrees of freedom, and the whole aircraft, with 27,446 elements, had 30,502 degrees of freedom. There were 9,188 input data cards. The multilevel substructure tree is shown in Figure 3.

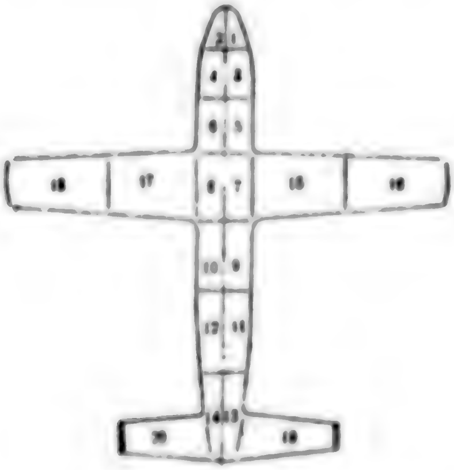

Figure 2. Substructures of a certain aircraft

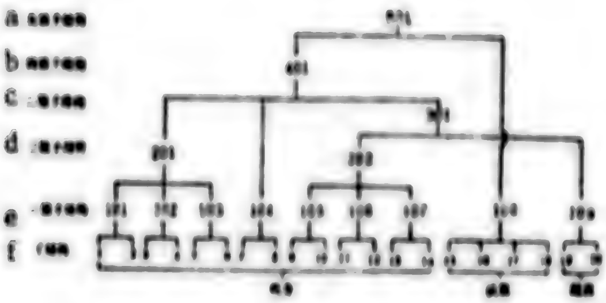

Figure 3. Multilevel substructure tree

Key:

a. Fifth level substructures
b. Fourth level substructures
c. Third level substructures
d. Second level substructures
e. First level substructures
f. Substructures

CWKZ(1)	Indicates performance of error diagnostics
SJSH	Data generation
KGSX	1/2, 3/4, 5/6, 7/8, 9/10, 11/12, 13/14, 15/16, 17/18, 101 (1, 2), 102 (3, 4), 103 (5, 6), 104 (7, 8), 105 (9, 10), 106 (11, 12), 107 (13, 14), 108 (15, 16, 17, 18), 109 (19, 20), 201 (101, 102, 103), 202 (105, 106, 107), 301 (202, 109), 401 (201, 301), 501 (401, 108). Tree structure for the calculation; 1/2 indicates that substructures 1 and 2 are symmetrical, and 102 (1, 2) indicates that first-level substructure 01 consists of substructures 1 and 2. The rest is analogous.
JL05	Fixed routine proceeding from assembly of stiffness matrix to stress computation.
DY	(Z01YSYL, 100; Z02YSYL, 101, Z03YSYL, 102, Z04YSYL, 103) Printout: stress on first substructure; element stress for second substructure with residual strength coefficient $\eta > 0.95$; element stress for third substructure where $\eta > 1.3$; stress, η, and nodal force on components of fourth substructure with maximum residual strength.
WAN	Program completed.

HAJIF-1's capabilities are limited to solving linear static problems at constant temperature. Such problems as dynamic analysis, stability analysis and linear influence analysis of materials and geometry will be solved in later versions of the structural analysis system. HAJIF-1 will be transferred to a larger and more modern computer.

Details of the aircraft structural analysis system can be found in the "Description of the Aircraft Structural Analysis System, Version 1 (HAJIF-1)," in the the "Aircraft Structural Analysis System Version 1 (HAJIF-1) User's Manual," and in a succession of articles which will appear in aviation journals and conferences on computational mechanics.

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CSO: 4008

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TITLE: "Supersonic Sail Wing"

SOURCE: Beijing HANGKONG ZHISHI [AERONAUTICAL KNOWLEDGE] in Chinese No 11, Nov 80 p 14

ABSTRACT: This article introduces a new wing design which can provide improved performance of a supersonic aircraft by utilizing favorable shock wave interference effects. In particular, the physics of shock wave formation over a wing during supersonic flight is explained. A specific sail wing design developed by the McDonnell Douglas Company is introduced and a tutorial discussion is presented to illustrate how the lift-to-drag ratio of the wing can be enhanced by taking advantage of the high pressure region below the wing surface which is created by an oblique shock wave emanating from the aircraft nose.

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ORG: None

TITLE: "Infrared Homing Guidance"

SOURCE: Beijing HANGKONG ZHISHI [AERONAUTICAL KNOWLEDGE] in Chinese No 11, Nov 80 pp 20-21

ABSTRACT: Infrared homing guidance is a passive guidance technique most commonly used on air-to-air missiles. It uses optical sensors which can seek targets that emit infrared radiation. In general, an infrared homing device employs the proportional navigation guidance scheme which steers the missile according to the measured angular rate of the line-of-sight rotation between the target and the missile. An infrared homing system has the following components: 1) optical system; 2) photo-sensitive detector; 3) signal voltage modulator; 4) electronic circuits; and 5) tracking mechanism. Current research efforts in infrared homing guidance are concentrated in the development of highly sensitive detectors, fast-response tracking mechanisms, and automatic search and track capability.

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TITLE: "High Altitude Simulation Test Platform for Aircraft Turbo Engines"

SOURCE: Beijing HANGKONG ZHISHI [AERONAUTICAL KNOWLEDGE] in Chinese No 11, Nov 80 pp 28-29

ABSTRACT: A high altitude simulation test platform is designed to create the pressure and temperature conditions of high altitude environment in order to test the performance of aircraft engines. Specifically, its functions are to: 1) certify and modify engine performance; 2) provide performance curves for airplane design; 3) eliminate engine troubles during flight; and 4) provide new data for high altitude engine research. In this article, the basic units of a high altitude simulation test platform are introduced and the simulation process of creating the stagnation temperature and pressure conditions of engine inlet and the static pressure condition of engine exhaust are explained. The key components of a test chamber which include the front chamber, the flow regulating screen, the inlet nozzle, the rear chamber, and the thrust measuring device are described.

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TITLE: "MATRA Super 530 Air-to Air Missile"

SOURCE: Beijing HANGKONG ZHISHI [AERONAUTICAL KNOWLEDGE] in Chinese No 11, Nov 80 pp 32-34

ABSTRACT: The MATRA Super 530 is a new French air-to-air missile to be equipped on the MIRAGE F-1 fighter airplane. It is designed specifically to intercept high altitude, high speed airplanes such as the MIG-25. The MATRA Super 530 was developed on the basis of its predecessor, the MATRA R530 missile and was first deployed by the French Air Force in December, 1979. The operation of a MATRA Super 530 missile can be either manually controlled with the aid of a fire control radar or automatically controlled by an on-board computer. The main advantages of the MATRA Super 530 missile are as follows: 1) good aerodynamic characteristics with high degree of mobility, stability, and high speed (Mach 4-5) capability; 2) highly sensitive guidance system with high-gain antenna, guidance computer and auto-pilot; 3) solid propellant engine to provide high thrust-to-weight ratio; 4) warhead with a kill radius of over 20 meters and a radio-controlled fusing device; 5) light-weight honey comb steel structure which can withstand high temperature created by aerodynamic heating.

3012
CSO: 4009

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TITLE: "Amelioration of Cadmium Soil in Changshi Irrigation Area and Prevention of Cadmium Contamination in Rice"

SOURCE: Beijing HUANJING KEXUE [ENVIRONMENTAL SCIENCE] Vol 1 No 5, 30 Oct 80 pp 7-11

ABSTRACT: The study on how to ameliorate the cadmium soil in the Zhangshi irrigation area of Shenyang, and prevent cadmium contamination in rice concludes that: 1) lime is the best amendment in terms of its neutralization of acidic soils, inhibition of rice absorption of cadmium from soils irrigated with acidic heavy metallic sewage, and economy; 2) pH is the main factor that affects rice absorption of cadmium,

[Continuation of HUANJING KEXUE Vol 1 No 5, 30 Oct 80, pp 7-11]

which drops against rising pH; and 3) rice absorption of cadmium is mainly at the later stage of growth, and therefore, more frequent irrigation at the earing stage is recommended for the prevention.

The authors express thanks to Vice-director Gao Zhengmin [7559 2163 3046] of the Institute, and Professor Yao Guigeng [1202 2981 5087] of Shenyang Agricultural College for reading and correcting the manuscript.

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TITLE: "Preliminary Study on Photochemical Smog Pollution at the Siqu District of Lanzhou"

SOURCE: Beijing HUANJING KEXUE [ENVIRONMENTAL SCIENCE] Vol 1 No 5, 30 Oct 80 pp 24-30

ABSTRACT: The study on the photochemical smog pollution over the Siqu district of Lanzhou shows that the frequency of such photochemical smog derived from nearby heavy and chemical industries can be higher than 35%, and the degree of pollution is indeed serious. The causes of such photochemical smog pollution is attributed to the strong solar radiation through the atmosphere that contains definite concentration of nitrogen oxides, crabohydrides and sulfur dioxide. Contrary to those at Los Angeles, the smog here is caused mainly by discharged waste gases from nearby industries.

The author expresses thanks to the Department of Environmental Chemistry of the Beijing University for direction and assistance, and to Prof. Tang Xiaoyen [0781 1321 3508] for reading the manuscript.

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TITLE: "Preparation of a Dispenser for Oil Spills"

SOURCE: Beijing HUANJING KEXUE [ENVIRONMENTAL SCIENCE] Vol 1 No 5, 30 Oct 80 pp 62-66, 47

ABSTRACT: Based on a study on the characteristics of HLB values and surface active agents in the compounding of highly efficient and low toxic oil spill dispensers, the author reports the preparation of two such preparations, with the adoption of such low toxic emulsifying agent as the ester type non-ionic surface active agent and paraffin hydrocarbon solvents. The HLB values for best emulsifying efficiency was found to be a tertiary compounding of EO(4), EO(11) and EO(6) oleats, but subject to the surface active agents composed of polyethylene oleate and polyethylene sorbitolate at appropriate proportions. The properties of the preparations with regard to their emulsifying power, biological toxicity, biological breaking, flash point and viscosity are finally evaluated.

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TITLE: "Application of High Gradient Magnetic Separation to Water Pollution Control"

SOURCE: Beijing HUANJING KEXUE [ENVIRONMENTAL SCIENCE] Vol 1 No 5, 30 Oct 80 pp 71-75

ABSTRACT: Advocating the advantages of the modern application of high gradient magnetic separation to water pollution control, the authors introduce the basic principles of the physical phenomenon of high gradient magnetic separation, the structure and separation of high gradient magnetic separators, and its application to the treatment of sewage from iron and steel industries, urban water works, and cleaning of drinking water. It is anticipated that adoption of superconductor technique will further increase the magnetic gradient, decrease power consumption, extend the separation range, and reduce cost, that water circulation will be further perfected, while river and lake pollution eliminated.

11,206
CSO: 4009

Geography

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TITLE: "Studies on Land Types in Mountain Regions North of Beijing"

SOURCE: Beijing DILI XUEBAO [ACTA GEOGRAPHICA SINICA] in Chinese Vol 35 No 3, Sep 80 pp 187-199

TEXT OF ENGLISH ABSTRACT: The mountain regions north of Beijing occupy the western part of Yan Shan which runs eastward to Shanhaiguan and forms the northern border of the North China Plain. The climate belongs to the semi-humid warm temperate type, with a cold winter and a hot summer. Average annual precipitation is about 800 mm in the front ranges and decreases to about 500 mm in the sheltered valleys. Deciduous forest of a semi-xerophytic type is the common vegetation. Drap soil is developed under this climatic and botanical environment.

Field investigations revealed that a great variety of landscape exists in this mountain region. A system of classification of land types has been attempted. This classification is based on the knowledge of physical geography and especially on the analysis of the physical factors controlling the differentiation of the landscape.

First, altitudinal zonation has to be considered. Although the altitude is not

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very high, from about 50 m in the foothills to over 2,000 m at the summit, vertical zonation of natural landscape is clearly manifested. Three vegetation-soil zones may be distinguished:
1. The lower part of the mountain, below 1,200 m, is covered by shrubs and grasses of semi-xerophytic and meso-xerophytic types. Small patches of *Pinus tabulaeformis*, *Quercus dentala* and *Fraxinus bungeana* may be found here and there in sheltered and protected areas. This is a secondary growth, the result of interference of human activities since historic times. Deprived of the protection of forest cover, erosion is very intensive on this part of the mountain. Mass wasting, such as mudflows, is a common feature which causes great damage to property and loss of life.
2. Above 1,200 m and up to 1,850 m is the second zone. It is rather well covered by a deciduous forest, dominated by various species of oak (*Quercus aliena*, *Q. variabilis*, *Q. accussima*), birch (*Betula platyphylla*, *B. duhurica*) and poplar (*Popular davidiana*). Shrubs and grasses form the undergrowth of the deciduous forest, but they are different species from those in the lower mountains. Brown forest soil is the typical soil. Due to the protection of the forest cover, mudflows seldom occur in this zone.
3. Above 1,850 m to the top of the mountain the deciduous forest is superseded by mountain meadow which is underlaid by a layer of black meadow soil. It constitutes a distinctive zone by itself. The meadow is used for pasture during the summer.

Next to altitudinal zonation, lithology deserves special attention. Lithological character is an important factor in the formation of landforms, soils and vegetation. For example, we found granite and limestone forming a very different landscape in this part of Yan Shan. Granite usually forms rounded or undulating landforms, covered with a thick layer of regolith and a mixed forest of pine and oak. Brown forest soil is developed wherever granite occurs. In limestone areas karstic landforms are found, with only a thin veneer of weather materials. Cypress (Biota orientalis) usually takes the place of pines. Drap soil is usually developed wherever limestone occurs. Loess which appears in different altitudes forms a typical landscape by itself, characterized by flat or undulating top and vertical slope under water erosion. The typical soil is drap soil, most of the loess-covered land being cleared for cultivation. Alluvial deposits along the valley constitute another type of landscape. The new deposits beside the river channel form flood plains, while the older deposits further away from the river form terraces. The flood plains and terraces are the most fertile land in the mountain region and become the center for agriculture and settlement. However, the occurrence of summer floods may be a hazard to the crops and inhabitants in the valley.

Mountain landscape is further diversified by the erosion of running water. Mountain slopes are intensively dissected and form mesorelief and microrelief. Slopes may be gentle or steep, convex or concave. The effect of aspects of slopes is also quite evident. In the upper part of the deciduous forest zone, south facing slopes are usually covered by shrubs and grasses and only the north facing slopes are forested with deciduous trees. In the lower mountain zone, the south facing slopes are usually cleared for growing fruit trees while the north facing slopes are forested with pines.

Based upon the analysis mentioned above, the land units are organized into a hierarchy of descending size as follows:

Order I. (Land system or mestnostch), altitudinal zone with common type of climate, vegetation and soil, without regard to geological and geomorphic features. Lithological and geomorphic differences may form a sub-order within the zone.

Order II. (Facet or urochishche), a part of the altitudinal zone formed by grouping of different facies, having common mesorelief, rock materials, drainage, vegetation and soil.

Order III. (Facies or element), simplest unit of landscape, with homogeneous lithology, microrelief, drainage, microclimate, vegetation and soil.

All the units are recurrent in their distribution within the respective order. The individual units (local forms) are grouped into abstract forms (species) according to their homogeneity or similarity. Species of land units may be further grouped into association.

The procedure of mapping and classification of land units may proceed from lower order (smaller size) to higher order by grouping of the smaller units into larger units or, vice versa, by subdividing the larger units into smaller units.

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Mapping of land types was carried out on different scales. For the larger units, e.g., the land systems, a map on the scale of 1:200,000 has been produced. This is suitable for the use of the provincial authorities. For the facets, a map on the scale of 1:100,000 has been produced. This is intended for the use of the county. A few maps for distribution to land units of the lower order (facies) have also been prepared on the scale of 1:10,000. These may be used by the commune. It has been found that not all facies can be shown even on the scale of 1:10,000, so some facies have to be left out or combined.

In this report the abstract land units are described, with descriptions on area, distribution, landforms, water conditions, soil, vegetation and land utilization, which would be convenient for reference.

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TITLE: "Mulberry-Dyke--Fish-Pond on the Zhujiang Delta--A Complete Artificial Ecosystem of Land-Water Interaction"

SOURCE: Beijing DILI XUEBAO [ACTA GEOGRAPHICA SINICA] in Chinese Vol 35 No 3, Sep 80 pp 200-209

TEXT OF ENGLISH ABSTRACT: The "Mulberry-Dyke--Fish-Pond" system is a peculiar farming method developed by the working people as a result of making full use of land and water resources in their longtime farming practice in the Zhujiang Delta. It is an interrelated system which brings into full play the production potential and makes reasonable use of land-water resources. It promotes the development of different branches of agriculture and its related processing industry. "Mulberry-Dyke--Fish-Pond" is a complete scientific ecosystem.

Mulberry-Dyke--Fish-Pond is characterized by its complex and diversified cycle. Mulberry growing, sericulture and fish breeding are interrelated. They promote each other and their circulating operation is complex and diversified. In terms of the food chain, the whole operation follows the following pattern: mulberry leaves are fed to silkworms, silkworm excreta is fed to fish, and mud from the fishpond is used as good manure for mulberry trees. This circulating process begins with mulberry growing, then moves on to sericulture and ends up with fish farming. In this closely related process, each link has either a positive or adverse effect on the others. There is a popular saying in Shunde which goes something like: The more luxuriant the mulberry trees, the stronger the silkworms, the fatter the fish, the richer the pond, the more fertile the dyke and the more the cocoons. This illustrates in full the circulation relation of Mulberry-Dyke--Fish-Pond. In this system the mulberry tree is the producer making use of sunlight energy to produce mulberry leaves, the silkworm is the first consumer eating mulberry leaves, the fish is the secondary consumer having silkworm excreta (and pupas) as food, and the plankton in the pond is the reduction agent bringing the organic substances, such as N, P and K, back to the pond.

The producing cycle of mulberry growing, sericulture and fish farming has as its base the circulation of substances in soil, water and living beings between the pond and dyke. The relations of mulberry trees, silkworms and fish to dyke, pond and atmosphere are those of substance-energy exchange and transformation between living beings and environment. Any change in morphology, productivity, quality, etc., during the growing process of mulberry trees, silkworms and fish is the result of interaction between mulberry trees, silkworms, fish and elements of the environment, such as temperature, light, water, air, soil, etc.

With an interdependent relationship between the living beings and environment, the Mulberry-Dyke--Fish-Pond is a complete ecosystem in which substance circulates and

energy is exchanged and transformed. It is a scientific farming method as well. In various cycles, big or small, the mulberry is the base and the fishpond is the key link. The pond can feed fish as well as the dyke. With the pond being taken good care of, there can be high yield in fish, and that also promotes the output of other crops.

The role of the Mulberry-Dyke--Fish-Pond is:
(1) Bringing into full play the potential of the local resources. Located in the southern subtropical zone, each year large quantities of mulberry leaves are collected, enough to feed eight to nine batches of silkworms, hence eight to nine batches of cocoons. Fish fry from the middle and lower parts of the Xijiang River are made use of in the development of pond fish farming. The river water and tidal water are made use of in self-control drainage and irrigation all year round. Mud from rivers and ponds is used as an important manure. Silkworm excreta is used to feed fish. Thus the land is being made full use of.
(2) Abundant sources of income and huge economic gains. The average income from every mu of mulberry trees (including that from mulberry leaves, cocoons, fish, vegetables, dry land crops and mulberry branches) is 400-500 yuan. If cocoons are exported, income will be increased, about four times that of rice, and three times that of sugarcane.
(3) A large labor force can be accomodated and is needed to do both heavy and light work.

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TITLE: "On Natural Zonation in Shaanxi Province"

SOURCE: Beijing DILI XUEBAO [ACTA GEOGRAPHICA SINICA] in Chinese Vol 35 No 3, Sep 80 pp 210-218

TEXT OF ENGLISH ABSTRACT: The division of natural zones is decided by the features of all round natural conditions. Since the formation of natural zones is mainly controlled by zonal factors, taking climatic conditions into consideration, heat, water, soil, vegetation and the characteristics in agricultural production should be regarded as criteria in the division of natural zones. Because these phenomena are mirrored in the soil, vegetation and agricultural differentiation, Shaanxi Province can be divided into the following eight natural zones:
(1) Sub-zone of semidesert steppe--brown desert steppe soil;
(2) Zone of dry steppe covered by wind-blown sands--light chestnut soil;
(3) Zone of dry steppe--light textured heilu soil;
(4) Zone of forest steppe--gray forest soil and argillaceous heilu soil;
(5) Zone of semi-arid deciduous broad-leaf forest and forest steppe--drab soil;
(6) Zone of mixed forest of coniferous and broad-leaf trees--burozem and drab soil;
(7) Zone of deciduous broad-leaf forest and evergreen broad-leaf forest--Cinnamon Yellow soil and Brown Yellow soil;

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(8) Sub-zone of evergreen broad-leaf forest--Yellow earth.
Of course clear boundary lines do not always exist since one natural zone may shade into another.

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TITLE: "On the Deterioration of Water Quality and Its Control After Large-Scale Reclamation in the Tarim Basin"

SOURCE: Beijing DILI XUEBAO [ACTA GEOGRAPHICA SINICA] in Chinese Vol 35 No 3, Sep 80 pp 219-231

TEXT OF ENGLISH ABSTRACT: The Tarim Basin below the confluence of the Yarkant, Hotan and Aksu Rivers has been one of our chief irrigated agricultural areas for the past 2,000 years, of which more than one million mu of virgin lands have been turned into farmland during the last 20 years. Such a large-scale land reclamation will certainly impinge on the natural environment of the basin, resulting in both favorable and unfavorable feedback, one of which is the deterioration of water quality.

Along the Tarim River, total dissolved salts which were chiefly composed of SO_4·Cl·HCO_3 - Na·Ca·Mg ions did not occupy more than one percent of the total water weight in the late 1950's and early 1960's. However, by the middle 1970's salinity had increased by five to eight times in the flowing water level period and chemical composition had changed into the Cl-Na type.

Groundwater in the newly reclaimed areas had undergone an even more conspicuous

[Continuation of DILI XUEBAO Vol 35 No 3, Sep 80 pp 219-231]

change. Before 1958, in a belt with a width of about 10 km along the Tarim River, the groundwater table was about 4-6 meters beneath the land surface in the upper and middle reaches and 3-8 meters in the lower reaches, while salinity of the groundwater did not rise above 1-3 g/l in general. However in 1973, after 15 years of cultivation, the groundwater table generally rose upward to 1-3 meters beneath the land surface and the salinity of the groundwater rose to 3-10 g/l, and even to 30-50 g/l in local depressions. Variations in groundwater tables and salt content have occurred in the adjacent non-reclaimed areas.

There can be only one conclusion. In view of protecting natural resources and ameliorating water quality, we must henceforth make better use of water resources in the Tarim Basin and effective measures, based on and according to specific natural features in different areas, must be taken.

AUTHOR: GU Tingmin [7357 1656 2404]
GONG Dewen [1362 1795 2429]
SHEN Jianzhu [3088 1696 2691]
CHEN Enjiu [7115 1869 0036; deceased]

ORG: GU and GONG both of the Meteorological Service of Shandong Province; SHEN and CHEN both of the Institute of Geography, Chinese Academy of Sciences

TITLE: "Climatic Regionalization of Drought and Flood in Shandong Province"

SOURCE: Beijing DILI XUEBAO [ACTA GEOGRAPHICA SINICA] in Chinese Vol 35 No 3, Sep 80 pp 232-241

TEXT OF ENGLISH ABSTRACT: In the past, most of the climatic regionalizations in China only showed dry and humid degrees of the atmosphere. In this paper, surface data of 126 meteorological stations and 90 hydrological stations were used to discuss the climatic regionalization of drought and flood in Shandong Province. We introduce a concept of effective precipitation, utilizing precipitation, potential evaporation and surface runoff to denote a drought and flood index, $DW = E/P(1-\sigma)$. Here, E is the potential evaporation, P the precipitation, σ the surface runoff coefficient and $P(1-\sigma)$ the effective precipitation. According to this index, we can get a climatic regionalization of drought and flood but not a climatic regionalization of dry air and humidity.

Since this index has seasonal variations, we calculated the drought and flood index

[Continuation of DILI XUEBAO Vol 35 No 3, Sep 80 pp 232-241]

of four different seasons:
Spring (March, April, May) $DW_1 = 0.6E/P(1-\sigma)$
Early Summer (June) $DW_2 = 0.7E/P(1-\sigma)$
Mid-Summer (July, August) $DW_3 = E/P(1-\sigma)$
Autumn (September, October) $DW_4 = 0.7E/P(1-\sigma)$.
These calculating values are used as criteria dividing Shandong Province into 14 subdivisions.

The index of drought and flood is examined by the water budget and soil and actual drought and flood conditions. A table includes DW values of the index of drought and flood compared with actual drought and flood at Dezou Shi, Lin Xian and Ju Xian in 1963-1972. Classes of drought and flood in the table are taken as the following: DW value of 0.5 is a major flood, 0.51-0.75 a flood, 0.76-1.25 normal, 1.26-2.00 a drought, and DW value > 2.00 a major drought. We found that the index DW defines the climatic regions of drought and flood rather well.

AUTHOR: DENG Yangxin [6772 7402 9515]

ORG: Lanzhou Institute of Glaciology and Cryopedology, Chinese Academy of Sciences

TITLE: "A Snow Avalanche in the Guxiang Region of Xizang and Its Role in the Physical Geographic Processes of High Mountains"

SOURCE: Beijing DILI XUEBAO [ACTA GEOGRAPHICA SINICA] in Chinese Vol 35 No 3, Sep 80 pp 242-250

TEXT OF ENGLISH ABSTRACT: During the investigations on the Guxiang mud-rock flow in Xizang from 1964 to 1965, we also observed the distribution, damage, types, activity and forms of snow avalanches and their roles in the physical geographic processes of high mountains.

The main contents in this paper are as follows:
1. The distribution and activity of snow avalanches.
2. The favorable conditions for snow avalanches.
3. The types of snow avalanches.
4. The role of snow avalanches in the physical geographic processes of high mountains:
(1) The geologic and geomorphologic functions of snow avalanches;
(2) The function of snow avalanches in the nourishment of glaciers;

[Continuation of DILI XUEBAO Vol 35 No 3, Sep 80 pp 242-250]

(3) The influence of snow avalanches on plant cover;
(4) The relationship between snow avalanches and mud-rock flow.
5. The influence of snow avalanches on constructional works in mountainous regions.

AUTHOR: WU Chen [0702 1820]

ORG: Geographical Institute of Hebei Province

TITLE: "Relationship of Water and Sand Eruption to Alluvial Sand Bodies in the Tangshan Earthquake Area"

SOURCE: Beijing DILI XUEBAO [ACTA GEOGRAPHICA SINICA] in Chinese Vol 35 No 3, Sep 80 pp 251-258

TEXT OF ENGLISH ABSTRACT: During the great 1976 Tangshan earthquake with magnitude 7.8, a large-scale water and sand eruption occurred on the ground surface of Tangshan district. Based on field survey and aerial photo interpretation, it is evident that the spatial distribution of water and sand eruption, including the eruption density, morphological character and various extending orientations and their figurations, was associated not only with the sand bodies of macro-geomorphic units, but also with the micro-geomorphic types, especially the ancient river channels. Accordingly, we concluded that the distribution of water and sand eruption is controlled by alluvial sand bodies and the nature of water and sand eruption is determined by geomorphic types.

As for the occurrence of water and sand eruption, in addition to shock force with relevant energy, a thicker layer of shallow buried and water-saturated fine silt, which was covered or uncovered by clayey loam, is a necessary condition. Since

[Continuation of DILI XUEBAO Vol 35 No 3, Sep 80 pp 251-258]

some geomorphic types, such as river flood plains, mid and peripheral portions of alluvial fans, marine plain and shallow buried ancient river channels, comprise the above-described sedimentary structure, and a strong earthquake gives a forceful shock to those geomorphic types, water and sand may easily erupt from underground to surface. Therefore, in seismological research, the geomorphologists should accurately demarcate the above-mentioned geomorphic types, whereas the engineers should pay particular attention to shock-proof measures on such geomorphic types.

9717
CSO: 4009

AUTHOR: JIANG Hongdi [5592 3163 4574]

ORG: Institute of Radiation Medicine

TITLE: "Unfolding Whole Energy Range Neutron Spectrum from Activation Data by Nonlinear Programming Method"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 241-248

TEXT OF ENGLISH ABSTRACT: This paper introduces a new method in which nonlinear programming is applied to determine the whole energy range neutron spectrum from the activation data. According to the different measuring conditions, a set of appropriate analytical expressions containing some undetermined parameters is selected or developed to describe the neutron spectrum to be measured. Then, an objective function is defined on the basis of the physical requirements of the measurement of the spectrum and minimized by means of nonlinear programming to obtain the optimum solution that satisfies the given reaction rates. Thus, a stable, convergent and continuous panoramic energy spectrum can be obtained while the appearances of spectrum oscillation and negative valued fluxes are completely avoided.

As an example, detailed results of the spectrum measured in channel No 1 of the Qinghua reactor are given. The incident neutrons are filtered by natural boron

[Continuation of JILIANG XUEBAO Vol 1 No 4, Oct 80 pp 241-248]

and lead, and the materials of the foils used are Mg, Al, S, Ni, In, Na, Mn, Co, Cu and Au.

AUTHOR: None

ORG: Research Group for JLG Laser Interferometer

TITLE: "JLG Laser Interferometer for the Automatic Measurement of Highly Accurate Gauge Blocks"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 249-257

TEXT OF ENGLISH ABSTRACT: The JLG laser interferometer is a new device for automatically measuring the highly accurate gauge blocks. Some advanced techniques are adopted in the interferometer, such as stabilized laser, electronic digital display, white-light interference fringes for automatically locating the surfaces of gauge blocks with a hollow corner cube prism and automatic control, etc. The limiting error of measured results for the instrument is

$$\Delta_{lim} = \pm (0.03 + 0.2L)\mu m$$

where L is the length of the measured gauge block in meters.

AUTHOR: LIU Yunzhu [0491 0336 5053]
MA Runshan [7456 3387 1472]
GUO Zhengqiang [6753 2973 1730]

ORG: None

TITLE: "The Exposure Standard"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 258-265

TEXT OF ENGLISH ABSTRACT: An exposure standard apparatus developed in NIM is presented. The exposure range of the apparatus is from 0.001 to 10 lux · second, the uncertainty of the exposure not exceeding ± 0.01 logarithmic unit. It basically satisfies the requirements of sensitometry and can be used to calibrate different types of sensitometers.

AUTHOR: None

ORG: Research Group for Photometric Primary Standard, NIM

TITLE: "The National Photometric Primary Standard of China"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 266-274

TEXT OF ENGLISH ABSTRACT: This paper gives a summary of the equipment and experimental results of the photometric primary standard of China. A method has been found for reducing the luminance fluctuation of the freezing platinum blackbody. The fluctuation may be reduced to within ± 0.3 percent from one freezing to another one. The luminance of the blackbody at the platinum freezing point agrees with that at the melting point within 0.2 percent. Our experience with platinum ingot No 2 showed that it was not contaminated after being used over 300 times. The total uncertainty of the photometric primary standard is ± 0.33 percent.

AUTHOR: CHEN Hongpan [7115 1347 4323]
CHEN Shouren [7115 1343 0088]
CHU Zaixiang [5969 6528 4382]

ORG: All of Harbin Industrial University

TITLE: "The Evaluation of the Emissivity and Temperature of Cavities at the Gold Freezing Point"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 275-286

TEXT OF ENGLISH ABSTRACT: According to the IPTS (68), Planck's formula is used to define the temperature above the freezing point of gold (1064.43°C). At present, the instrument adopted by most countries to realize the scale is the photoelectric pyrometer which is used directly for observing the spectral radiance of the bottom of a graphite cavity enclosed by pure gold. Because the depth-radius ratio of the cavity is large and the cavity wall is very thin, the error caused by the deviation from 1 of the apparent emissivity of the bottom and the temperature difference between the internal and external walls is negligible. However, in practice, when the stable thermal equilibrium is established at the gold freezing point, there is always a constant thermal flux radiating outward through the cavity opening which causes the inner wall temperature to always be lower than the gold freezing point.

In the present investigation, the integral equation for the temperature

[Continuation of JILIANG XUEBAO Vol 1 No 4, Oct 70 pp 275-286]

distribution inside the cavity and the relation between the emissivity and local temperature have been derived according to the basic ideas of Geist. These equations have been solved using a computer for some cylindrical cavities and the results are given in this paper.

AUTHOR: ZHANG Baoyu [1728 2450 0810]

ORG: None

TITLE: "The Relations Between the Magnetic Fields of the Helix Current and the Current Sheet"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 287-295

TEXT OF ENGLISH ABSTRACT: By analyzing and comparing the magnetic field distributions for both the helix current model and the current model, it has been proved that the average of the field for the helix current over the polar angle is exactly equal to the field for the corresponding current sheet, no matter what the size of the pitch will be. As a matter of fact, the field for the helix current is equivalent to the superposition of the field for the current sheet and a small sinusoidal quantity, which can be neglected when the pitch is small enough. Furthermore, the integral average of the field for the helix current over the spherical sample placed at the center of the solenoid is equal to the center field. These results have practical importance for further development of the determination of the gyromagnetic ratio of protons in the weak field.

AUTHOR: ZHANG Zhonghua [1728 6945 5478]

ORG: None

TITLE: "A Matrix Perturbation Method for Calculation of Errors in Precision Electromagnetic Measuring Circuits"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 296-298

TEXT OF ENGLISH ABSTRACT: A matrix perturbation method for the calculation of errors in precision electromagnetic measuring circuits caused by small variations of circuit parameters is described in this paper. The formulae for the calculation are very simple and can be used for finding errors of any order. The convergence conditions for the perturbation procedure are also given and discussed.

AUTHOR: FENG Xinshan [7458 2450 0810]
WU Youzhang [0702 1635 3864]

ORG: None

TITLE: "A Broadband Coaxial Low Power Standard"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 299-302

TEXT OF ENGLISH ABSTRACT: The broadband coaxial calorimeter described in this paper is developed as the national coaxial low power standard. The calorimeter is of the twin-load type, one load being the calorimetric body while the other provides a reference of temperature. RF power is measured by comparing with standard DC power. It operates in the frequency range of 1 to 8.2 GHz, and the total uncertainty is ± (0.17~0.26) percent.

The coaxial power meter is calibrated by means of the power equation concept. The calibration system is a three arm generalized reflectometer, and the total calibrated uncertainty is better than ± 0.27 percent.

AUTHOR: ZHANG Jucai [4545 0658 2088]

ORG: None

TITLE: "Some Experiments on the IEC-318 Recommendation for an Artificial Ear"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 303-306

TEXT OF ENGLISH ABSTRACT: Starting from a review of the IEC-318 recommendation for the artificial ear, analytical experiments were made for seven parameters of the analogical network with parameters varying one by one. Experimental curves and discussions are given.

AUTHOR: CHEN Shihua [7115 0013 5478]

ORG: None

TITLE: "A Fast Logarithmic Charge Amplifier for Liquid Scintillation Counting Device"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 307-315

TEXT OF ENGLISH ABSTRACT: This paper describes a fast logarithmic charge amplifier. Using this amplifier in a liquid scintillation counting device, absolute measurements of the activity of some radionuclides have been realized. The problem of closed-loop stability of logarithmic converters employing a bipolar transistor as logarithmic feedback element is discussed. A method for measuring the dynamic range of the fast logarithmic charge amplifier is described. Finally, the results of absolute measurement of the activity of several radioactive solutions by this device are given.

AUTHOR: ZHANG Lisheng [1728 0500 3932]

ORG: None

TITLE: "Technical Requirements for VCXO Used in the Cesium Atomic Clock"

SOURCE: Beijing JILIANG XUEBAO [ACTA METROLOGICA SINICA] in Chinese Vol 1 No 4, Oct 80 pp 316-320

TEXT OF ENGLISH ABSTRACT: Voltage controlled crystal oscillator (VCXO) plays an important role in the atomic frequency standard. The performance of VCXO must be excellent so as to maintain the inherent frequency accuracy and stability of the atomic standard. Through analysis, technical requirements for VCXO used in the cesium atomic clock are put forward in this paper.

9717
CSO: 4009

AUTHOR: HOU Guoben [0186 0948 2609]
LU Lisheng [4151 7787 3932]

ORG: HOU of Shandong College of Oceanology; LU of the Ministry of Transport

TITLE: "The Hydraulic Model Study of Vertical Shaft Axial Flow Pumps Used for Installation in Docks"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 1-12

TEXT OF ENGLISH ABSTRACT: Critical values of energy loss parameters are established as a basis for the proportioning approach to channel passages in hydraulic models on pump intakes. Models that satisfy the critical limits when adjusted experimentally to yield zero swirl of the suction pipe inlet have been found to give reliable indications of full scale behavior, both in regard to swirl correction and freedom from air entrainment.

This report suggests general results for use by design engineers engaged in power stations, pumping stations or dock design, and illustrates them by several examples of successful designs.

AUTHOR: XI Pan'gen [1153 4149 2704]
ZHANG Shuzhen [1728 3219 3791]
FENG Shizuo [7458 1102 460A]

ORG: All of the Department of Physical Oceanology

TITLE: "Mathematical Modeling of Circulation in the East China Sea"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 13-25

TEXT OF ENGLISH ABSTRACT: Based on the "wind curl-thermohaline gradient equation" proposed by Feng, one of the authors of this paper, and taking actual bottom fluctuation into account, a two-dimensional numerical model of steady-state circulation driven by a nonuniform surface wind and the thermohaline effect is presented. The model is applied to the East China Sea. The computations of winter circulation exhibit considerable agreement with the observed current field. The trend of circulation is almost parallel to isobaths. The Kuroshio exerts great influence on the southeast part of the area in question where the swift current flows nearly along the isobath for 200 meters, its main part outflowing from the east boundary of the region, while the other, the smaller one, flows and branches into the Tsushima Current and the Yellow Sea Warm Current. In the northern part of the waters there exists a counterclockwise "Yellow Sea Gyre System" consisting of the northward Yellow Sea Warm Current and the southward China Coastal Current. At the southwest end of the area, the Min-Zhe Branch of the Kuroshio together with the Taiwan Strait Counter Current flows south in a semi-arc pattern along the north coast of Taiwan Island.

The influence of boundary forces, the thermohaline effect, wind stress vorticity and water depth on the circulation are estimated respectively. The computations show that the circulation pattern of the East China Sea, under the action of boundary forces (especially the Kuroshio System), depends basically on the bottom topography, with the thermohaline effect playing a determinant role in generation of the counterclockwise "Yellow Sea Gyre System." The wind stress, however, only acts as an adjustment factor and is of less importance.

AUTHOR: SHEN Yujiang [3088 5148 3984]

ORG: Department of Physical Oceanology

TITLE: "Numerical Computation of Tides in the East China Sea"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 26-35

TEXT OF ENGLISH ABSTRACT: For the East China Sea the hydrodynamical equation system of the co-oscillating tides is numerically solved by giving the values of tidal harmonic constants at the boundaries. Based on the computed results the co-tidal charts of four main constituents are drawn. With the help of the charts the propagation behaviors of tidal waves in the region are analyzed, and the formation of amphidromic systems and the distribution of tidal characteristic quantities are described. The author is of the opinion that there exists a semidiurnal degenerate amphidromic system near Jilong, Taiwan.

The comparison between the computations and observations exhibits excellent agreement, thus suggesting that our results can serve general purposes.

AUTHOR: LIU Liansheng [0491 5571 3932]
ZHANG Zhengbin [1728 2973 2430]

ORG: Both of the Department of Marine Chemistry

TITLE: "A Study of the Mutual Non-Interference Effect of Inorganic Ion Exchange in Seawater. II. Theoretical Explanation and New Experimental Verification of the Mutual Non-Interference Effect of Inorganic Ion Exchange in Seawater"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 36-52

EXCERPT FROM ENGLISH ABSTRACT: This article attempts to give a theoretical explanation of the mutual non-interference effect of inorganic ion exchange in seawater. Some new experimental results are presented for confirming the mutual non-interference effect of inorganic ion exchange in seawater.

AUTHORS: YU Zhili [0670 5268 7787]
DAI Guosheng [2071 0948 7105]
WANG Hong [3769 4767]
et al.

ORG: All of the Department of Marine Chemistry

TITLE: "Determination of Nitrate in Seawater by Cadmium-Copper Reduction Method"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 53-61

TEXT OF ENGLISH ABSTRACT: The method based on that described by Grasshoff has been tested and the conditions of the method have been modified. The results show that temperature and salinity do not influence the determination of nitrate. The diameter of the cadmium grain was selected. If a suitable flowing rate, reduction column length and cadmium grain diameter from 7 to 40 mesh are controlled, an excellent recovery of more than 95 percent and high precision and sensitivity can be obtained. This method would be suitable for on-board routine analysis of nitrate contents in seawater.

AUTHOR: WANG Qingzhang [3769 1987 1864]
TAN Yunhua [6151 1471 5478]

ORG: Both of the Department of Marine Chemistry

TITLE: "Determination of Sulfide in Seawater by Electrochemical Membrane Sulfide Electrode"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 64-74

TEXT OF ENGLISH ABSTRACT: A method is described for the determination of sulfide in seawater by an ion selective electrode in which the electroactive membrane is made up of Ag_2S formed by an electrochemical technique. The background electrolyte solution is 1 M NaOH containing 5 mg/ml ascorbic acid as the antioxidant reagent. A linear Nernst response with the slope of 29.8 ± 0.2 mv/log $C_{S^{2-}}$ is obtained over the total sulfide concentration range from 10^{-3} M to 10^{-7} M for seawater having different salinities (5~35 percent). The average standard deviation of the observed potentials is 0.6 mv, and the relative standard deviation of the sulfide concentration is 5 percent. The experimental recovery of sulfide is 101 ± 3 percent. The detection limit of sulfide is about 6 x 10^{-8} M. The interference of some heavy metals on the electrode response was tested, and the obvious interference of Cd, Pb and Cu can be eliminated by the addition of Na_2H_2EDTA and [illegible] respectively. Data obtained for the seawater samples by the calibration curve, standard addition and graphical method are in good agreement.

AUTHOR: HUANG Weixun [7806 5633 2429]
HE Chunqi [0149 2504 2660]
ZHANG Xiaxun [illegible]

ORG: All of the Department of Marine Chemistry

TITLE: "Determination of Lead and Cadmium in Aqueous Environments by Anodic Stripping Voltammetry"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 75-79

TEXT OF ENGLISH ABSTRACT: A method for the determination of lead and cadmium by anodic stripping voltammetry with a general oscillographic polarograph fitted with a glassy graphite electrode has been investigated. The range of determination is 10^{-6}–10^{-10} M. The method is simple and rapid and has been successfully applied to river water, seawater and polluted water samples.

AUTHOR: HU Zengmiao [5170 1073 8693]

ORG: Department of Marine Biology

TITLE: "The Determination of ^{40}K Contents of Some Marine Organisms of the Yellow Sea and the Bohai Sea"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 80-85

EXCERPT FROM ENGLISH ABSTRACT: The contents of ^{40}K for some marine organisms collected from the Yellow Sea and the Bohai Sea were determined. The results of the determination are summarized.

AUTHOR: CHEN Weisheng [7115 4850 0524]
FANG Zongxi [2455 1350 3356]

ORG: Both of the Department of Marine Biology

TITLE: "Some Effects of Indole-3-Acetic Acid (IAA) on Female Gametophytes of *Laminaria japonica*"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 86-90

TEXT OF ENGLISH ABSTRACT: In the present experiments three different sources of the female gametophytes of *Laminaria japonica* were used to study the biological effects of IAA. It was observed that higher concentrations (more than 10 ppm) of IAA chemical had evident lethal effects, and lower concentrations (such as 0.01 ppm, 0.1 ppm and 1 ppm) showed some effects of stimulation, that is, promoting vegetative growth of the female gametophytes. In mixed populations of female and male gametophytes the IAA effect was seen to be less obvious.

It is interesting to note that female gametophytes from different sources responded differently. It is believed that this difference might be due to different genotypes of the gametophytes. Another point worth mentioning is that IAA showed an inhibiting effect on the maturation of the gametophytes. As a result, the development of sporophytes was somewhat delayed when treated with IAA.

AUTHOR: CHEN Kuanzhi [7115 1401 2535]

ORG: Department of Marine Biology

TITLE: "The Anatomy of the Central Nervous System of *Penaeus orientalis* and *Portunus trituberculatus*, and Comparative Morphology of the Nervous Chain of Decapoda"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 91-99

TEXT OF ENGLISH ABSTRACT: The central nervous system of *Penaeus orientalis* consists of the following: Two pairs of ganglia, which belong to the anterior part of the head, form the brain of the animal. Four pairs of nerves arise from the brain, the first pair leading to the antennules, the second to the compound eyes, the third to the antennae and the fourth to the tegument of the head. From the back of the brain there emerges a pair of circum oesophageal connectives, which from either side of the oesophagus pass posteriorly to connect with the sub-oesophageal ganglion. The sub-oesophageal ganglion are made up of five pairs of ganglia. From the sub-oesophageal ganglion radiate five pairs of nerves on either side, these nerves supplying the mandibula, the maxillula, the maxilla, and the first and second maxillipeds, respectively. The thoracic nerve chain possesses five pairs of ganglia, from the anterior four of which arise nerves that supply the third maxillipeds, and first, second and third pereiopods respectively. The fifth pair of ganglion consist of two pairs of ganglia, from which arise two pairs of appendage nerves,

[Continuation of SHANDONG HAIYANG XUEYUAN XUEBAO Vol 10 No 3, 15 Sep 80 pp 91-99]

one pair to the fourth pereiopods and the other to the fifth pereiopods. Between the fourth and fifth thoracic ganglion there is an aperture which allows the passage of the sternal artery. The abdominal nerve chain possesses six pairs of ganglia, from which arise nerves that supply the five pairs of pleopods and one pair of uropods respectively.

The central nervous system of *Portunus trituberculatus* consists of the following: the brain of the animal appears to be similar to that of *P. orientalis*. However, in *Portunus* all of the ganglia of the ventral nerve chain are fused with the sub-oesophageal ganglion to form a large single mass from which arise all the nerves of the appendages in the mouth part, thorax and abdomen.

This paper gives a description and illustration of the comparative morphology of the nerve chains of every group of Decapoda so as to show the usual tendency toward concentration and fusion of the ganglion.

AUTHOR: SUN Ruiping [1327 3843 1627]
WU Baoling [0702 1405 6845]
YANG Dejian [2799 1795 3362]

ORG: SUN and WU both of the Institute of Oceanology, Chinese Academy of Sciences; YANG of Shandong College of Oceanology

TITLE: "A Study of the Morphology and Larval Development of the Neanthes japonica (Izuka) from the China Sea"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 100-110

EXCERPT FROM ENGLISH ABSTRACT: This report is part of the study on the morphology and larval development of species of the family Nereidae found in the China Sea.

Neanthes japonica (Izuka) is a specific species in China and Japan. It is usually most abundant in sandy-mud sediments and estuaries of the Bohai (Dalian, Beidaihe, Tianjin, Yantai), the Yellow Sea (Qingdao, Weihai) and the Changjiang River (Shanghai).

Neanthes japonica and N. diversicolor are very similar in morphology, but they are different in reproduction. During the spawning season, N. japonica was found in the marine regiments. They were collected on 15 March 1963, at temperatures of

[Continuation of SHANDONG HAIYANG XUEYUAN XUEBAO Vol 10 No 3, 15 Sep 80 pp 100-110]

8-10°C in the sea water of Qingdao. The larvae developed slowly and settled on the 21st day with seven-setiger nectochaete. Settlement and metamorphosis occurred in a relatively short period of time because in only three days it metamorphosed from seven-setiger nectochaete to ten-setiger juvenile.

The sequence of the early embryology and larval development is summarized.

AUTHOR: WANG Weixin [3769 4850 2450]
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ORG: WANG Weixin of the Department of Marine Physics; WANG Qingzhang of the Department of Marine Chemistry

TITLE: "A Useful Potentiostat in Voltammetry"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 111-116

TEXT OF ENGLISH ABSTRACT: A potentiostat for compensating potential drop at IR and electrode polarization in voltammetry has been constructed from an operational amplifier. It is conveniently used for three-electrode voltammetry when measurements have to proceed in very dilute solutions, organic mediums or have to operate with micro-electrodes. The operational amplifier circuit of the potentiostat and experimental results of the three-electrode system compared with a two-electrode system were detailed.

AUTHOR: LIU [illegible] [0491 6647 0679]
WANG [illegible] [3769 7364 5115]
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[illegible] [1776 3525 1813]
WANG Weixin [3769 4850 2450]
ZHAO Yushi [6392 3768 5347]

ORG: All of the Department of Physical Oceanology

TITLE: "An Instrument Measuring Gradients of Temperature, Humidity and Wind Speed Above Sea Surface"

SOURCE: Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 10 No 3, 15 Sep 80 pp 117-125

TEXT OF ENGLISH ABSTRACT: The principle, method, application and accuracy of an instrument which measures gradients of temperature, humidity and wind speed above the sea's surface are described.

The instrument can be used to measure gradients of the above-mentioned quantities within 2 meters above the sea's surface at four different heights. The sensor detecting temperature and humidity is a pt resistor ($R_0 = 500$), and the sensor sensing wind speed is a cup anemometer. The signals of temperature, humidity and wind speed are converted by an A-D circuit and digitally displayed. These

[Continuation of SHANDONG HAIYANG XUEYUAN XUEBAO Vol 10 No 3, 15 Sep 80 pp 117-125]

sensors are set on a buoy, the yan of which will be less than 5° under Beaufor wind scale 5. The signals are transmitted by a calle of 20 cores to a digital display system on board. The accuracies of measurement are:

± 0.05°C (for temperature),
± 3% (for humidity) and
± 0.2 m/sec (for wind speed).

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AUTHOR: WANG Jiangang [3769 0256 0474]

ORG: None

TITLE: "Lofty Ships Watch the Skies: Missile Range Instrument Ships in Space Technology"

SOURCE: Beijing JIANCHUAN ZHISHI [KNOWLEDGE OF SHIPS] in Chinese No 7, 20 Oct 80 pp 2-3

ABSTRACT: When China conducted an intercontinental ballistic missile test on 18 May 1980, a number of ships were waiting for the splashdown at latitude 7° S, longitude 171° 33' E. They included instrument ships, recovery ships and others. Before the missile splashed down, the instrument package was ejected, and was recovered from the ocean by a diver descending from a helicopter. The role of instrument ships in space technology is described on the basis of the ships used in the United States Apollo program. These ships, with displacements ranging from 12,000 to 21,600 tons, were equipped with S band and C band radars for tracking purposes. Diagrams are used to describe the procedures in the launch stage, orbit stage, reentry stage and landing stage.

AUTHOR: ZHANG Shipei [1728 0013 3099]

ORG: None

TITLE: "Favorites in the Energy Crisis: Energy-Saving Ships"

SOURCE: Beijing JIANCHUAN ZHISHI [KNOWLEDGE OF SHIPS] in Chinese No 7, 20 Oct 80 pp 12-13

ABSTRACT: The 65,000 ton Japanese ship Aramo has attracted great attention because of its energy-saving design, which cuts fuel consumption by a quarter. The two main ways of saving on fuel, which may be consumed at the rate of 65 tons or more a day, are to lower the most efficient screw rotation speed and to use waste heat recovery measures. Changes in propeller rotating speed require larger propeller blades, which encounters the limiting factor of available space. Waste heat recovery is aimed at recovering some of the 60 percent of the total energy produced in combustion which is lost. Waste gases at up to 400° C are used to make steam in a waste heat boiler; the steam can be used to drive a steam turbine as an auxiliary propulsion source or an electric power generation unit, or for ship functions. The Aramo used the Kawasaki KSE system, with energy savings of 21-28 percent. The new Mitsubishi D/MAP system is more flexible than the KSE system since it has a clutch system which makes it possible to use steam power for either propulsion or power generation.

AUTHOR: YAO Jiajin [1202 1367 3866]

ORG: None

TITLE: "The Tomahawk Ship-Launched Cruise Missile"

SOURCE: Beijing JIANCHUAN ZHISHI [KNOWLEDGE OF SHIPS] in Chinese No 7, 20 Oct 80 pp 16, 15

ABSTRACT: The NATO response to deployment of the Soviet SS-20 is deployment of the US SSBS-2 and cruise missiles. The Tomahawk cruise missile can carry a conventional or 200-megaton nuclear warhead. It has a range of 1,700 miles and high accuracy. It can be launched from a submarine, from the Nimitz carrier or from Spruance class destroyers. Its primary guidance system is Terrain Contour Matching (TERCOM), in which radar altimeter measurements are compared with a stored digital map. Near the target, where this system renders the missile more easily detectible, an image matching system is used, tripling the accuracy. To defend against this, the Soviets will have to build many dummy installations, but the cruise missile is cheap, so many can be launched at targets. In the event of a major European war, Soviet Backfire bombers will launch AS-6 antiship missiles at NATO ships bringing troops and materiel to Europe. The cruise missile is the most effective means of destroying the Backfire bases. In addition, because US carriers are too few to cover all areas in which the US desires to exert influence, the use of cruise missiles aboard destroyers and cruisers in the Indian Ocean will be beneficial.

AUTHOR: LIN Hua [2651 5478]

ORG: None

TITLE: "The Styx Missile"

SOURCE: Beijing JIANCHUAN ZHISHI [KNOWLEDGE OF SHIPS] in Chinese No 7, 20 Oct 80 pp 22-24

ABSTRACT: During the 1967 Mideast war, the Israeli destroyer Eilat was sunk by 4 Styx missiles at a distance of 15 miles from Port Said, proving the importance of this weapon. The Styx, or SS-N-2, is an aerodynamic missile powered by a solid-fuel auxiliary motor and a liquid-fuel main rocket motor with a range of 35-40 km, which has been supplied by the Soviet Union to many countries. India used it to sink a Pakistani destroyer in the Indo-Pakistan war. It can be mounted on small, fast boats such as the Soviet Komar and Osa class. It flies low (100-300 meters, or as low as 10 meters) and is not maneuverable. By the 1973 war, Israel had developed the Gabriel antiship missile, which sank 9 Arab ships, while none of the small, fast Israeli missile boats was hit. Countermeasures were found to render the Styx guidance system ineffective.

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